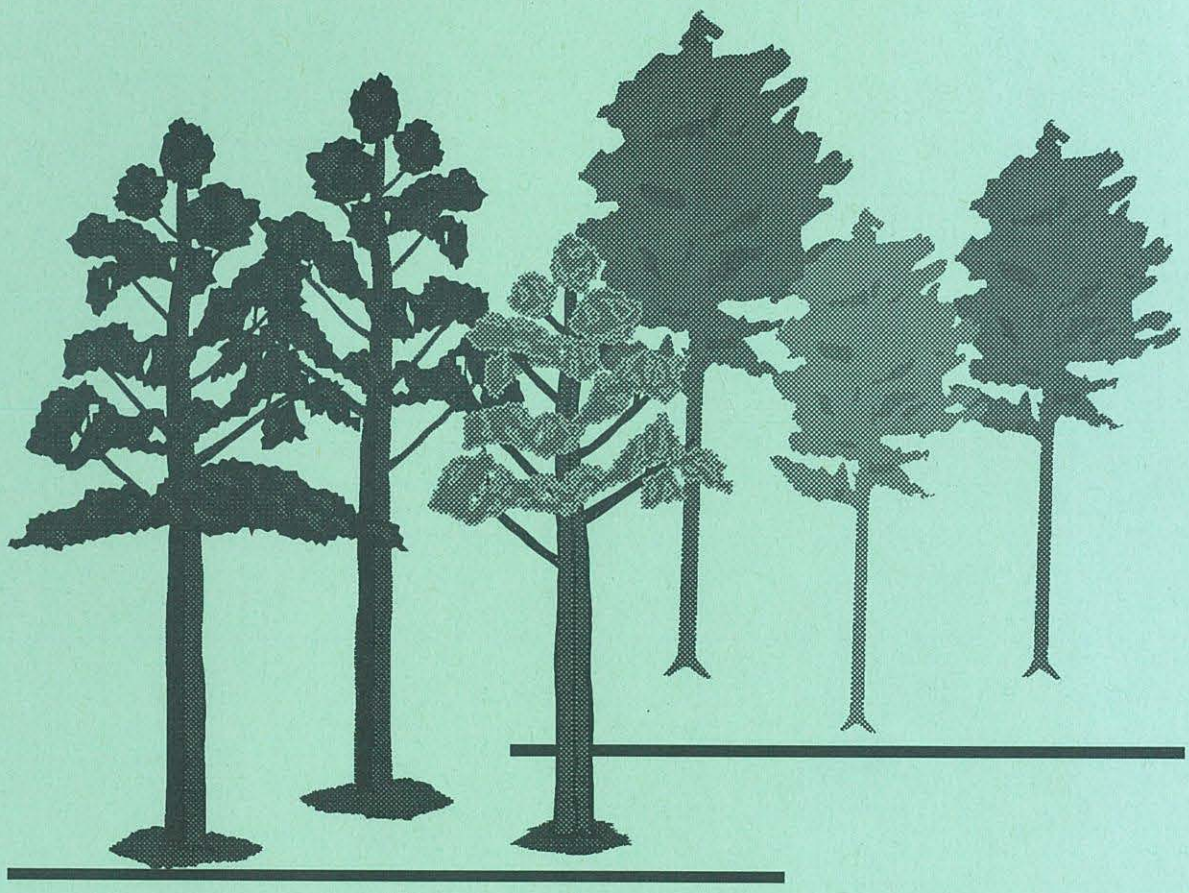
MICHIGAN FOREST HEALTH: SUPPLEMENTAL REPORT

1994



DNR

Michigan Cooperative Forest Pest Management Program

EQUAL RIGHTS FOR NATURAL RESOURCE USERS

The Department of Natural Resources provides equal opportunities for employment and for access to Michigan's natural resources. Both State and Federal laws prohibit discrimination on the basis of race, color, national origin, religion, disability, age, marital status or sex under the Civil Rights Acts of 1964 as amended, MI PA 453 and MI PA 220, Title V of the Rehabilitation Act of 1973 as amended, and the American Disabilities Act. If you believe that you have been discriminated against in any program, activity or facility, or if you desire additional information, please write the office of Human Resources, U.S.Fish and Wildlife Service, Washington, D.C. 20240; or the MDNR Equal Opportunity Office, PO Box 30028, Lansing, MI 48909 or the Michigan Department of Civil Rights, State of Michigan, Plaza Building, 1200 6th Ave., Detroit, MI 48226.

For information or assistance on this publication contact the Michigan Department of Natural Resources, Forest Management Division, PO Box 30452, Lansing MI 48909-7952, or phone 517-373-1275.

Printed by the Authority of Michigan Department of Natural Resources, Forest Management Division. Total Number of Copies Printed: 500. Total Cost: $1,463.20. Cost Per Copy: $2.93.

Michigan Forest Health: Supplemental Report 1994

Carolyn J. Randall
Editor

Published by:

Michigan Department of
Natural Resources,
Forest Management
Division

Michigan Forest Health:
1994 Supplemental Report

August 1995

PREFACE

Overview of the Michigan Cooperative Forest Pest Management Program

The Michigan Cooperative Forest Pest Management Program is firmly dedicated to helping fulfill forest management objectives by providing forest land managers with practical pest management information to improve decision making. In existence since the mid-1970's, the program brings together expertise from seven cooperating organizations.

Member institutions of the Michigan Cooperative Forest Pest Management Program include:

Michigan Department of Natural Resources

Michigan Department of Agriculture

Michigan State University

Michigan Technological University

University of Michigan

USDA Forest Service NCFES

USDA Forest Service NE Area State and Private Forestry

Directors of the Forest Pest Management Program are:

Robert A. Haack, USDA Forest Service, and John F. Witter, University of Michigan, Co-Directors of Research and Development

Deborah A. McCullough, Michigan State University, Co-Director of Technology Transfer

Frank J. Sapio, Department of Natural Resource, Co-Director of Field Applications

Purpose of the *Michigan Forest Health: Supplemental Report 1994*:

The *Michigan Forest Health: Supplemental Report 1994* is the Forest Pest Management Program's tenth cooperative report. This report is meant as a follow-up on research projects presented in the *Michigan Forest Health Report: 1991-1993*. There are also additional research projects presented that pertain to Michigan forest health that had not been included in previous Forest Pest Management Program reports. The report is also meant to serve as a supplement to the *Michigan Forest Health Report: 1994* (to be published at a later date) which contains information on the pest management programs and the resource condition of state-owned forests in Michigan's Upper Peninsula and northern Lower Peninsula. Contributors to the report include forest pest specialists and forest health specialists from universities, government agencies, and extension. The time that they take to inform the Michigan forest land manager about the results from research and development projects helps all of us keep abreast of Michigan's forest health and pest management issues and concepts.

Where to Obtain a Copy of the 1994 Forest Health Report:

Copies of the *Michigan Forest Health Report 1994* are available from the Michigan Department of Natural Resources, Forest Management Division, 8th Floor Mason Bldg., Box 30452, Lansing, MI 48909-7952, c/o Frank Sapio.

CONTRIBUTORS

(in alphabetical order)

Bertsch, Robin
Michigan Department of Natural Resources

Bauer, Leah
USDA Forest Service

Davis, Terry
Michigan State University

Ellis, Tom
Michigan State University

Fullbright, Dennis
Michigan State University

Haack, Robert
USDA Forest Service

Hajek, Ann
Cornell University

Hart, John
Michigan State University

Heyd, Robert
Michigan Department of Natural Resources

Kielbaso, J. James
Michigan State University

Lawrence, Robert
USDA Forest Service

Leutscher, Bruce
University of Michigan

Linderman, Sheila
Michigan State University

Mahalak, William
Michigan Department of Natural Resources

McCullough, Deborah
Michigan State University

Mech, Roger
Michigan Department of Natural Resources

Randall, Carolyn
Michigan State University

Roberts, Dave
Michigan State University

Sapio, Frank
Michigan Department of Natural Resources

Smitley, Dave
Michigan State University

Stehr, Fred
Michigan State University

Stoyenoff, Jennifer
University of Michigan

Stubblefield, Andy
University of Michigan

Wildenthal, Rebecca
Consumers Power, Co.

Witter, John
University of Michigan

TABLE OF CONTENTS

PREFACE i

CONTRIBUTORS iii

CONTENTS iv

GLOSSARY OF TERMS vi

FOREWORD ix

1994 FOREST HEALTH: INVENTORY AND ANALYSIS

MICHIGAN'S GROWING AND EXPANDING FOREST RESOURCE 1

Forest Acreage Increases 1

Timber Volume Increases 1

Timber Productivity Gains Possible 2

Forest Protection: Cooperative Effort 2

BASELINE SURVEY OF FOREST CONDITIONS IN HARDWOOD FORESTS OF LOWER MICHIGAN 2

NORTHERN FOREST HEALTH MONITORING 6

1994 FOREST HEALTH: GYPSY MOTH

POST-SPRAY EVALUATION OF THE MICHIGAN COOPERATIVE GYPSY MOTH SUPPRESSION PROGRAM IN 1994 9

INTRODUCTION AND ESTABLISHMENT OF *ENTOMOPHAGA MAIMAIGA* IN MICHIGAN 12

Introduction 12

Results 12

THE USE OF COLOR AERIAL PHOTOGRAPHY FOR ESTIMATING HOMOGENEITY OF DEFOLIATION LEVELS AND STAND COMPOSITION IN GYPSY MOTH DEFOLIATED FORESTS 15

THE 1994 RELEASE OF THE PREDATORY BEETLE *CALOSOMA SYCOPHANTA* (COLEOPTERA: CARABIDAE) AGAINST THE GYPSY MOTH IN MICHIGAN 16

Introduction 16

Methods 16

Conclusions 17

1994 FOREST HEALTH: OTHER INSECT PESTS
LARGER PINE SHOOT BEETLE 19
YELLOWHEADED SPRUCE SAWFLY 20
ASSESSING JACK PINE BUDWORM IMPACTS IN MICHIGAN'S UPPER PENINSULA 20
Survey Methods 20
Results 21
1992-1994 Survey Summaries 22
Discussion 23

1994 FOREST HEALTH: OTHER DISEASE AND PEST PROBLEMS
INTRODUCTION OF A BIOLOGICAL CONTROL TO MANAGE CHESTNUT BLIGHT IN MISSAUKEE COUNTY MICHIGAN 25
PREDISPOSING FACTORS INVOLVED IN RED PINE POCKET MORTALITY 27
Introduction 27
The Role of Soil Acidification 28
Results and Discussion 28

1994 FOREST HEALTH: URBAN FORESTS
MICHIGAN STREET TREES: AN ASSESSMENT OF TWENTY CITIES - 1994 31
Introduction 31
Methods 32
Results 32
Planting Needs 34
Conclusion 35
MANAGEMENT OF *DIPLODIA* TIP BLIGHT OF PINES 37
DIAGNOSING TREE PROBLEMS 38
CANKER SORES ON TREES? 39

GLOSSARY OF TERMS

The following is a list of terms from the fields of forestry, forest pathology, and forest ecology that appear in various articles throughout this report.

For further definitions the reader is referred to *Terminology of Forest Science, Technology, Practice and Products*, 1983, published by the Society of American Foresters, and from which some of these definitions were derived.

B.t. — *Bacillus thuringiensis*, a naturally occurring bacterium that affects certain caterpillars and is used as a biological control in suppression programs aimed at gypsy moth and some other insect pests.

Basal Area — Tree cross-sectional areas as computed for **DBH** measurements. The basal area for an entire stand of trees is often expressed as square feet per acre or square meters per hectare.

Biomass — The total quantity of living plants and/or organisms at a given time, usually expressed in weight per unit area.

Board Foot — A unit of lumber measurement having dimensions of 1 foot (length) by 12 in. (width) by 1 in. (thickness).

Bole — The main tree stem or trunk.

Callus — Undifferentiated tissue that forms over a wound or cut plant surface; functions in wound healing.

Canker — A depressed and/or discolored area on the stem or branches of a tree caused by invasion by a pathogenic organism(s) and death and decay of **host** tissues.

Canopy — A closed layer of tree crown cover, usually referring to the uppermost layer.

Chain — A unit of linear measurement traditionally used in forestry to measure horizontal distances. One chain is 66 feet long.

Codominant — An expression of crown class which refers to trees with crowns in the upper forest canopy and receiving full light from above, but tend to have slightly smaller, moderately sized crowns as compared to trees in the **dominant** size class.

Cord — A measurement of wood cut for fuel or pulpwood (128 cubic feet, as arranged in a pile 8 feet long, 4 feet high, and 4 feet wide).

Cordwood — Wood stacked or sold in cords.

Crown — The top part of the tree that includes the needles/leaves.

Crown Class — Determined by the position and size of a tree's crown within the forest canopy, the four major crown classes are **dominant, codominant, intermediate** and **suppressed**.

DBH — Diameter-at-breast height, the diameter of the tree as measured from 4.5 feet above the ground.

Decline — The gradual failure in health of a tree, often (but not solely) associated with diseases of complex origin--i.e. diseases caused by more than one stress-inducing factor of both biotic and abiotic origin.

Dieback — A symptom of tree decline in which branches appear to be dying from the tip back, often characterized by early fall coloration and leaf drop.

Dominant — An expression of crown class which refers to trees with crowns in the upper forest canopy and receiving full light from above. They are larger than the average trees within a stand and have well-developed crowns.

Ecosystem — A system made up of communities of plants, animals and microorganisms and their interrelated physical environments, and includes both the organic and inorganic aspects involved in the cyclic processes of life.

Epizootic — An outbreak of disease affecting many animals of one kind at the same time.

Host — Any organism upon which another (parasitic) organism lives on, deriving nourishment and/or protection.

Hypovirulent — Refers to strains of a pathogen that have relatively less capacity to cause disease.

Intermediate — An expression of crown class which refers to trees with crowns in the middle to upper canopy. They are shorter and have smaller crowns than the **dominant** and

codominant size classes and receive little direct light from above.

Lumber — Pieces of wood no further manufactured than by sawing, planing, crosscutting to length and perhaps edge-matching.

Merchantable — Refers to pulpwood or saw log sections that meet pulpwood or saw log specifications, respectively.

Mycorrhizae -- Fungi which form symbiotic associations with the root cells of certain plants, thus functioning as root hairs and increasing absorption of nutrients.

NPV — Nuclopolyhedorsis virus; a naturally-occurring virus that infects gypsy moth larvae.

Overstory — The trees in a forest of more than one story that form the upper or uppermost canopy layer.

Pioneer — A plant capable of invading bare sites (i.e. newly disturbed) and persisting there until supplanted by successor species.

Poletimber — Commercial species generally greater than 4 or 5 inches DBH but too small to be **saw logs**.

Primary Pest — The organism that initially stresses the tree, weakening it and predisposing it to attacks by **secondary pests**. It is often associated with **decline** diseases of complex origin.

Pulpwood — Wood that is used in making paper.

Rotation Age — The recommended age for harvesting of a mature stand of trees based on physiological and economic variables.

Saw log — A log meeting minimum standards of diameter, length, and freedom from defect. Saw logs are taken from sawtimber trees.

Sawtimber — Commercial species containing at least a 12-foot log or two noncontiguous saw logs 8 feet or longer.

Secondary Pest — The organism(s) which is attracted to a tree that has been weakened by a primary pest, The primary and secondary pest(s) in combination with abiotic factors such as weather extremes and site conditions may lead to the eventual death of the tree. They are often associated with decline diseases of complex origin.

Shade Intolerant — Tree species that grow best under high light conditions and are thus adapted to colonizing open sites with little shade or crown cover.

Shade Tolerant — Tree species that grow best under low light conditions and are thus able to outcompete shade-intolerant species on the shaded forest floor.

Silviculture — the art and science of growing forests.

Site Index — An expression of the quality of a forest site as determined by the average height of **dominant** and **codominant** trees of a representative species within the forest type. It is usually expressed as **site index(50)** or the height of trees within the stand at 50 years of age.

Stand — A community of naturally or artificially established trees of any age sufficiently uniform in composition, constitution, age, spatial arrangement, or condition to be distinguishable from adjacent communities thereby forming a silvicultural management entity.

Stand Volume — A measurement of the amount of timber at a silvicultural management site often expressed as **cords/acre**.

Succession — The gradual supplanting of one plant community by another over time.

Suppressed — An expression of crown class with refers to trees with crowns in the lower canopy and receiving little or no direct light from above.

Thinning — An intermediate cut made in an immature stand primarily to maintain or accelerate diameter increment and also to improve the average form of the remaining trees.

Understory — Trees and woody species growing under an **overstory**.

Vascular cambium — A thin layer of dividing cells that is responsible for secondary growth; in the main stem of trees the cambium is located between the bark and sapwood.

Veneer — Wood cut by slicing, peeling or sawing into sheets 1/4 in. or less in thickness.

FOREWORD

The articles contained in this report were written to inform forest land managers, forest health specialists, extension personnel, researchers, scientists, and the general public about the state of Michigan's forests. Overall Michigan's forests are in good health and continuing to improve. This is illustrated by Bertsch's article on the completion of Michigan's fifth forest inventory. According to the inventory, forestland acreages have increased 10 percent in Michigan since 1980. Michigan also has the fifth largest amount of timberland acreage in the United States and the potential to increase forest growth through full stocking of all timberland acres is substantial. In order to protect this resource, it is necessary to perform inventories and to monitor forest health conditions across the state.

Forest health concerns range from problems of anthropogenic origin, such as acid deposition, air pollution, introduced pests, and the possibility of global climatic changes; to naturally occurring phenomena such as periodic droughts, frosts, other weather/temperature extremes, and insect and disease epidemics. It is important to recognize and identify problems affecting forest health so that preventative and/or control measures can be established and impacts to the forest resource can be assessed. The Michigan Department of Natural Resources' Forest Health Program is essential to this process. By inventorying public and private forest resources, establishing forest stewardship programs, and identifying, mapping and monitoring disease and insect outbreaks, the Department can better manage and protect forest resources. Other programs that participate in tracking forest health such as the Michigan Impact Monitoring System (MIMS), a statewide program, and Northern Forest Health Monitoring (NHM), a national program, are summarized within this report.

These, plus other forest health monitoring programs, illustrate that cooperative effort between agencies enables more effective management of our forests. Gypsy moth management, for example, is one of the areas where the MDNR in cooperation with other agencies (i.e. Michigan Department of Agriculture, universities, county governments, etc.) is making some progress. Davis and Smitley report that acres treated with a biological control for gypsy moth (B.t.) had significantly less defoliation than untreated acres. They also report that gypsy moth populations are crashing in many areas of the state (even in untreated plots) due to a number of factors. Of primary significance is the increase in the activity of natural predators and parasites keeping gypsy moth populations low. In addition Smitley, *et al.* report success in introducing a natural fungal pathogen of gypsy moth into Michigan from the eastern states which is expected to spread rapidly across the state within the next five years. These, plus other suppression programs, including the release of a predatory beetle as reported by Ellis, *et al.*, will help keep gypsy moth levels low in the state.

Gypsy moth is not the only insect pest of significance to our state. Other pests such as the larger pine shoot beetle and the jack pine budworm are a concern and studies to control and manage these pests are outlined within this report (Haack and Lawrence; and Heyd, respectively). Aside from insect problems, forest health may be threatened by diseases of fungal origin. Chestnut blight, for example, has devastated forests on a national scale, yet few people seem aware of its impact. Studies are being made to control this disease, as reported by Fulbright, *et al.* with the goal of returning chestnut as a significant component of forest ecosystems. Aside from biotic causes for disease such as insects and fungi, diseases may also be of abiotic origin as suspected in the case of red pine pocket mortality as reported by Randall and Hart. Finally, the last chapter of this report outlines the status and our urban forests (Wildenthal and Kielbaso), a significant resource to our state.

This report falls quite short of the measure of providing a complete picture of the condition of our forests. The primary purpose, however, is to inform the public and to generate interest and support for the various programs and research projects that pertain to forest health. It is hoped that with public support and interest, forest health programs will continue to expand within the state. Comments, questions, and suggestions on this report can be directed to Frank J. Sapio, Forest Health Program Manager, MDNR Forest Management Division, 8th Floor Mason Bldg, Box 30452, Lansing, MI 48909-7952.

Carolyn J. Randall
Editor

1994 Forest Health Report: Inventory and Analysis

MICHIGAN'S GROWING AND EXPANDING FOREST RESOURCE

Robin Bertsch (MDNR)

Michigan's temperate forests are an abundant, diverse, healthy, productive and expanding asset providing a multitude of benefits to its citizens. These benefits include habitat for both flora and fauna, recreational and sight-seeing opportunities, filtration for air and water quality, and timber for societal consumption. Economic benefits to our state's economy are significant. Over $10 billion of value added and 180,000 jobs are annually supported statewide through forest-based industries and tourism/ recreation. These forests contribute significantly towards quality of life values shared by both residents and non-residents of our state.

The 1993 completion of Michigan's fifth statewide forest inventory since 1935, conducted in collaboration with the United States Forest Service—North Central Forest Experiment Station, provides essential data to assess statewide forest conditions. Forest stewardship policy alternatives are currently being discussed by broad representative interests to continue to improve forest health. These collective efforts will help ensure Michigan's forests continue to be healthy and productive while providing a multitude of sustainable benefits.

Forest Acreage Increases

Michigan's forests are extensive, covering more than half of its land base. They are located predominantly in the northern two thirds of the state. Forestland acreage totals 19.3 million acres, a 10% increase since 1980. Forestland classified as timberland must meet minimum timber productivity standards. This timberland acreage (18.6 million acres) is the fifth largest in the United States, exceeded only by the states of Georgia, Oregon, Alabama, and North Carolina. Timber land acreage has increased 7% since 1980.

Active forest management and protection activities have resulted in a maturing forest resource, increasing in both tree size and age. Sawtimber-sized tree stands now comprise 46% of the timberland acreage; poletimber and seedling/sapling tree stands comprise 30% and 24% respectively of the timberland acreage.

The temperate forests of Michigan contain a rich and diverse mix of tree species in an equally diverse forest type mix. The hardwood (broadleaf deciduous) forest types that comprise 75% of the total timberland acreage base include maple-beech-birch, aspen-birch, oak-hickory, and elm-ash-soft maple. Principle softwood (coniferous) forest types include red-white-jack pine, spruce-fir, and northern white cedar.

Ownership patterns of the forests within our state reflect the healthy and diverse cultural value systems of the individuals and institutions involved in the stewardship of these properties. The forest resource is owned predominantly by the private sector (65%). The nonindustrial private owner and farmer categories collectively control 57% of the total timberland acres, while forest industry has 8% of the ownership. The remaining 35% is controlled by the public sector (21% state owned; 14% federally owned). Active forest management and protection activities provide a basis for enhanced forest stewardship on each of these ownerships.

Timber Volume Increases

The timber volume associated with Michigan's forest acreage has demonstrated a remarkable ability to positively respond to both active forest management and protection programs. Growing stock (5 inches diameter and larger trees) inventory volume is 26.8 billion cubic feet in 1993, a 42%increase since 1980. The largest expansion of inventory volume is concentrated in the sawtimber-size trees. Sawtimber volume is 72 billion board feet in 1993, a 66% increase since 1980.

Annual changes in tree species growth and harvests, and the relationships between these changes, permits analysis of current and future forest condition. Net growth rates (reduced by natural mortality estimates) for growing stock and sawtimber are 831 million cubic feet and 3.1 billion board feet respectively in 1993 (increasing 38% and 77% since 1980). Growing stock and sawtimber harvests in 1990 were 324 million

cubic feet and 1 billion board feet respectively (reflecting increases of 35% and 22% since 1978). Annual forest growth is estimated to exceed annual forest harvests by over 150% (508 million cubic feet) for growing stock, and by 201% (2.1 billion board feet) for sawtimber. This situation bodes well for the forests of Michigan; these excess volumes of annual forest growth will be added to the inventory to further accumulate for the future needs of our citizens and society.

Timber Productivity Gains Possible

Opportunity to improve timber management and increase timber volumes within Michigan is significant. Relatively flat terrain, productive soil structure, and a good transportation network provide access to the majority of these forest lands. The potential to increase current forest growth by over 50% (to 1.3 billion cubic feet annually) is possible through full stocking of all timberland acres. The annual growth potential can be enhanced further through manipulative stand improvements, tree species conversion, and/or use of genetically improved tree species. Red pine, a native species, has the potential to produce as much wood volume per acre as slash and loblolly pine in the South. Use of genetically improved tree strains developed cooperatively by Michigan universities, industries, and government have shown productivity potentials in excess of 214 cubic feet per acre per year. The state-owned forests are postured to take advantage of an investment account, "Forest Development Fund," established to improve timber growth and yields on a portion of their forest lands.

Michigan has a well established and progressive reforestation industry able to meet the need well into the future. Seedling nurseries are capable of producing over 60 million trees annually. Over 50 tree planting contractors reside or operate within our borders.

Forest Protection: Cooperative Effort

A cooperative effort between local, state, and federal fire agencies plays a major role in the protection of Michigan's forest lands. Active fire prevention programs, the use of aerial detection techniques, highly specialized equipment development and use, and progressive ideas have brought recognition to Michigan as a leader in the protection of its natural resources. Prescribed burning is readily employed to reduce fire risk as well as improve silvicultural and wildlife habitat objectives.

Forest health protection is a integral part of resource protection. Insect and disease outbreaks as well as other stressors, such as climate and air pollution, are detected through ground and aerial surveys. Biological and socioeconomic factors are evaluated; then silvicultural, biological, and chemical management alternatives are considered; and finally the most appropriate alleviatory methods are implemented.

BASELINE SURVEY OF FOREST CONDITIONS IN HARDWOOD FORESTS OF LOWER MICHIGAN

J.A. Witter (U of M), J.L. Stoyenoff (U of M), B.A. Leutscher (U of M), F.J. Sapio (MDNR), and R. Mech (MDNR)

During the past ten years, there have been several major disturbances in oak, aspen, and northern hardwood stands throughout the Lower Peninsula of Michigan. Defoliation by the gypsy moth became a major disturbance in Michigan forests during the 1980s and remains a problem today. Also during this time period some hardwood forests experienced defoliation episodes from other insect species such as forest tent caterpillar, large aspen tortrix, saddled prominent, Bruce spanworm, or greenstriped mapleworm. Michigan's hardwood forests also have faced stress from severe drought, such as the 100-year drought episode that occurred in the summer of 1988. Additionally, frost plays a role in stressing forests. Frost stress occurs yearly in some localized areas due to physiographic factors, but it can also occur on a region-wide basis. For instance, several severe frost events occurred throughout large areas of lower Michigan during the late spring and early summer of 1992.

In order to understand the interactive stresses impacting Michigan forests and the effects that these stresses are having on forest health, a solid set of baseline data on the conditions of Michigan's most susceptible forest types was needed. Such information is necessary for making appropriate forest management decisions. No data sets of this type have been available for Michigan in the past. Therefore, in 1991 we began the Michigan Impact Monitoring System (MIMS) to survey conditions and stress factors in Michigan forests.

The MIMS system consists of 566 plots located in 283 stands throughout 33 counties in lower Michigan. Of these, 197 are oak stands, 48 are aspen stands, and 38 are northern hardwood stands. In each study stand, we established two 30 x 30 m plots in which we record data at the level of the individual tree for all trees greater than 5.0 cm DBH. Data collected include tree species, DBH

(diameter-at-breast height), crown position, and tree condition (live or dead). Information on tree height, live crown height, crown vigor, and current defoliation. Two 9 x 9 m subplots are also established within each of the large plots. In these subplots, we tallied all woody regeneration in 2 size classes (0.0-2.5 cm DBH, 2.6-5.0 cm DBH) and 5 species classes (maples, oaks, aspens, conifers, other hardwoods).

Recently, the first technical report from the MIMS project was published (Witter et al. 1994). Major findings of that report are summarized here. Oak, aspen, and northern hardwood forest types have basal areas averaging 124 sq. ft./acre, 142 sq. ft./acre, and 150 sq. ft./acre, respectively. The overall health of all three of these hardwood forest types is quite good (Table 1). Percent of basal area dead for these three forest types were 4.8%, 4.4%, and 2.4%, respectively. The vigor of the living trees also is good in general throughout all forest types. However, forest conditions do exhibit considerable differences among ecosystem units, forest stands, tree species, and crown classes within each of the forest types. For example, percent of standing overstory trees that were dead in the oak forest type ranged from—50% among different ecosystem units. There was considerable variation in mortality among species in the oak forest type: northern pin oak—19%, white oak—11%, red oak—7%, and red maple—5%. In all these forest types, trees in the dominant and codominant crown classes have relatively few dead stems with the exception of dominant and codominant northern pin oak in dry oak ecosystems (Tables 2, 3, and 4). However, tree mortality is generally much higher in the intermediate and suppressed crown classes of each forest type. Both the forest conditions and forest composition showed marked differences among counties and regions in Michigan.

Regeneration is good in the northern hardwood forest type in Michigan. Here, shade-tolerant species are replacing themselves as expected. However, in both aspen and oak stands, the species showing the best regeneration is red maple. In oak stands in particular, the amount of replacement regeneration is somewhat lower in the smaller size class (mean=100±21 stems/acre in the 0.0-2.5 cm DBH class) and is very poor in the larger size class (mean=8±3 stems/acre in the 2.6-5.0 cm DBH class).

We have revisited each MIMS stand annually to collect data on temporal changes that take place in the condition of overstory vegetation. Here, we report on changes that have taken place over a three-year period for those MIMS stands established in 1991 (Table 5). These data show that overstory oak mortality has increased over the last three years, particularly that of northern pin oak (1991—8.2% of stems dead, 1994—37.6% of stems dead). Percent of red oak stems dead in the oak forest type increased over the three-year period from 3.7% to 9.5%.

For more information on this study, contact John Witter or consult the following technical report:

Table 1. Data on forest conditions in three hardwood forest types of Michigan. Species within each forest type are arranged in order of descending value for mean basal area alive.

Forest Type	Species	Mean trees/acre	% of stems dead	Mean BA live (ft^2/acre)	Mean BA dead (ft^2/acre)	Mean vigor
OAK						
	red oak	95	7.0	44.4	1.1	1.7
	white oak	98	10.7	21.8	1.0	2.0
	red maple	120	4.9	13.4	0.3	1.4
	n. pin oak	26	19.3	11.8	2.0	2.2
ASPEN						
	bigtooth aspen	260	9.2	84.1	3.5	1.5
	red maple	130	5.1	17.5	0.3	1.3
	trembling aspen	104	14.5	15.2	1.2	1.4
NHW						
	sugar maple	359	4.9	83.4	1.4	1.4
	basswood	50	5.9	27.4	0.6	1.6
	beech	26	0.2	8.1	0.0	1.3

Witter, J.A., J.L. Stoyenoff, and B.A. Leutscher. 1994. The Michigan Impact Monitoring System: Baseline Final Report. *Mich. Coop. For. Pest Mgmt. Prgm. Tech. Rept. 94-2.*

Table 2. Data on forest conditions in three crown classes of the oak forest type in Michigan. Species within each crown class are arranged in order of descending value for mean basal area alive.

Crown Class	Species	Mean trees/acre	% of stems dead	Mean BA live (ft^2/acre)	Mean BA dead (ft^2/acre)	Mean vigor
DOMINANT/CODOMINANT						
	red oak	52	0.6	36.2	0.9	1.5
	white oak	20	0.6	14.0	0.3	1.7
	black oak	12	1.0	11.0	0.2	1.9
	n. pin oak	13	12.7	8.9	1.3	2.0
INTERMEDIATE						
	red oak	23	7.0	6.2	0.6	1.9
	red maple	22	0.7	4.5	0.1	1.2
	white oak	17	4.3	4.8	0.4	1.8
	n. pin oak	8	21.5	2.3	0.7	2.3
SUPPRESSED						
	red maple	93	0.1	0.3	0.3	1.4
	white oak	31	21.1	1.1	1.1	2.4
	red oak	21	23.1	0.6	0.6	2.3
	n. pin oak	6	32.0	0.3	0.3	2.8

Table 3. Data on forest conditions in three crown classes of the aspen forest type in Michigan. Species within each crown class are arranged in order of descending value for mean basal area alive.

Crown Class	Species	Mean trees/acre	% of stems dead	Mean BA live (ft^2/acre)	Mean BA dead (ft^2/acre)	Mean vigor
DOMINANT/CODOMINANT						
	bigtooth aspen	134	0.9	68.7	2.1	1.2
	trembling aspen	28	1.7	9.6	0.3	1.3
	red oak	9	0.0	7.1	0.0	1.6
	red maple	8	0.0	3.8	0.0	1.0
INTERMEDIATE						
	bigtooth aspen	71	7.4	12.8	2.0	1.7
	red maple	27	0.4	6.3	0.1	1.1
	trembling aspen	35	6.9	4.0	0.4	1.3
	red oak	5	6.9	1.4	0.2	1.9
SUPPRESSED						
	red maple	96	6.9	17.5	0.5	1.4
	bigtooth aspen	55	31.9	3.0	1.4	2.1
	trembling aspen	41	29.8	1.8	0.7	1.9

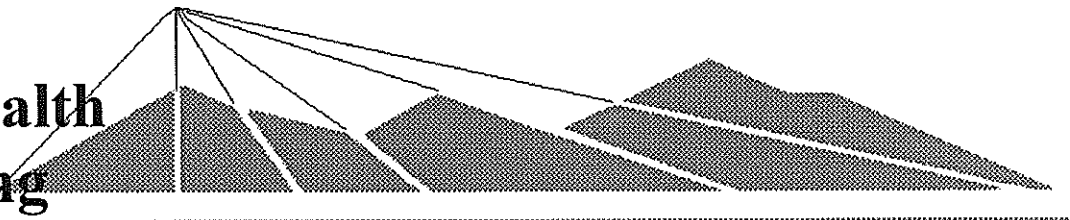
Table 4. Data on forest conditions in three crown classes of the northern hardwood forest type in Michigan. Species within each crown class are arranged in order of descending value for mean basal area alive.

Crown Class	Species	Mean trees/acre	% of stems dead	Mean BA live (ft^2/acre)	Mean BA dead (ft^2/acre)	Mean vigor
DOMINANT/CODOMINANT						
	sugar maple	96	0.7	54.1	2.1	1.2
	basswood	36	1.0	24.3	0.5	1.4
	white ash	14	0.8	10.7	0.1	1.5
	beech	7	0.0	5.5	0.0	1.1
INTERMEDIATE						
	sugar maple	70	1.0	16.6	0.5	1.2
	basswood	9	12.0	2.6	0.5	1.9
	beech	4	0.0	1.3	0.0	1.3
SUPPRESSED						
	sugar maple	192	8.3	12.7	0.9	1.7
	beech	14	0.4	1.3	0.0	1.5
	American elm	6	47.7	0.3	0.2	2.0

Table 5. Data on forest conditions in 45 oak stands measured annually from 1991-1994. Species are arranged in order of descending number of live stems.

	% of stems that are dead				mean vigor rating				mean defoliation			
# trees	1991	1992	1993	1994	1991	1992	1993	1994	1991	1992	1993	1994
red oak												
347	3.7	6.1	8.4	9.5	1.4	1.8	1.8	1.3	3.9	1.3	1.1	1.0
n. pin oak												
343	8.2	19.0	31.2	37.6	1.9	2.6	2.6	2.0	3.9	1.9	2.2	1.0
red maple												
234	2.1	3.0	3.0	3.8	1.2	1.3	1.3	1.1	1.6	1.1	1.0	1.0
white oak												
210	5.2	6.2	7.1	9.0	1.8	2.1	2.2	1.6	3.9	1.7	1.8	1.0
white pine												
54	1.9	1.9	1.9	1.9	1.1	1.3	1.3	1.2	1.3	1.1	1.0	1.0
bigtooth aspen												
38	16.2	16.2	21.6	24.3	1.5	2.1	1.8	1.5	4.1	1.4	1.3	1.0
black oak												
28	0.0	0.0	3.8	11.5	1.6	2.4	2.4	1.8	4.4	3.1	4.7	1.0

Northern Forest Health Monitoring



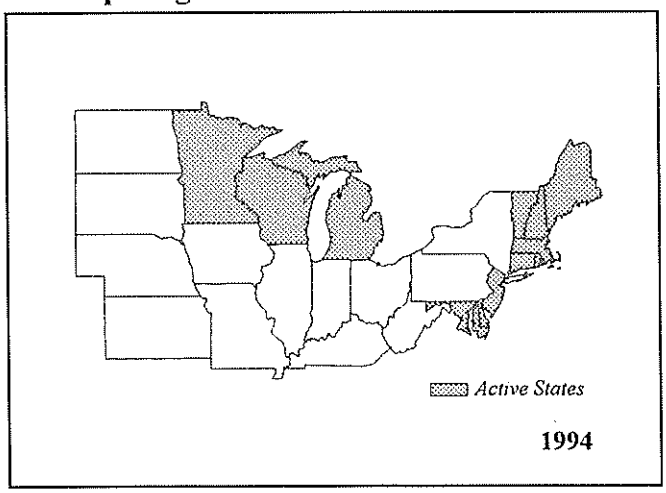
Introduction

Forests are valued not simply for forest products, but also for recreation, wildlife, fisheries, water quality, and aesthetics. In recent years, there has been considerable interest in the health of the Nation's forests and the potential threats from weather and climatic extremes (from droughts to floods), forests pests (native and introduced), global change, and acidic deposition. In order to respond to these concerns, the national Forest Health Monitoring (FHM) Program was implemented in New England in 1990 and now includes 20 states.

The term ***forest health*** describes forest conditions relative to human values, needs, expectations, and functions. ***Monitoring*** can be defined as the repeated measurement or sampling of information for comparison to a reference system or identified baseline. It always involves the determination of changes over time, usually interpreted against a baseline. FHM is a program designed to collect the appropriate ***forest health*** information over time ***(monitoring)***.

FHM is designed to annually collect, analyze, interpret and report on the conditions of all forests in the United States.

Participating States



Implementation

The basis for FHM is a set of plots distributed on a systematic grid across the entire US. Each detection plot represents approximately 160,000 acres. The Northern FHM program has 1139 detection plots currently in 12 states.

State	Year Implemented	Number of Forested Plots	Total Plots
Connecticut	1990	12	18
Delaware	1991	2	8
Maine	1990	127	137
Maryland	1991	16	37
Massachusetts	1990	23	32
Michigan[1]	1994	133	247
Minnesota[1]	1994	121	337
New Hampshire	1990	34	37
New Jersey	1991	16	30
Rhode Island	1990	2	4
Vermont	1990	24	35
Wisconsin[1]	1994	92	223
Total		**602**	**1145**

[1]estimates only because plots will be visited for the first time in 1994.

Measurements on the detection plots involve seven major groups or indicators. Mensuration, crown rating, damage assessment, and bioindicators have been measured since the beginning of the program. Vegetation diversity, lichens, and photosynthetically active radiation will be implemented for the first time in 1994 on a 1/4 subset of the detection plots.

Another important aspect of the program is information collected on the area and forest surrounding the detection plots. This includes forest insects and pathogens, weather and climate information, fire incidence and damage, and land use patterns. Both plot and "off-plot"information are required to interpret forest conditions.

Reprinted from Forest Health Monitoring, USDA Forest Service Northern FHM Program.

Program Organization and Participants

The Northern FHM program is coordinated by the USDA Forest Service Northeastern Forest Experiment Station and Northeastern Area State and Private Forestry in Radnor, PA. The regional program is cooperative with state forestry and agricultural agencies as full participants in the implementation of the program. The regional program is also provided assistance by cooperators in the National FHM Program with data management, quality assurance, weather and climate information, and equipment procurement. National cooperators include the US-EPA Environmental Monitoring and Assessment Program (EMAP), USDA Forest Service National FHM, US Bureau of Land Management, and the National Association of State Foresters.

Northern FHM Cooperators

Connecticut
Agricultural Experiment Station
Division of Forestry
Delaware Forest Service
Lumberjack Conservation and Resource District
Maine Forest Service
Maryland
Department of Agriculture
Forest, Park, and Wildlife Service
Massachusetts Division of Forests and Parks
Michigan Department of Natural Resources
Minnesota Department of Natural Resources
New Hampshire Division of Forests and Lands
New Jersey Division of Parks and Forestry
Rhode Island Division of Forest Environment
University of Massachusetts, Department of Forestry and Wildlife Management
University of Michigan, School of Natural Resources and Environment
USDA Forest Service
Northeastern Forest Experiment Station
North Central Forest Experiment Station
Northeastern Area State and Private Forestry, Forest Health Protection
Vermont Department of Forests, Parks, and Recreation
Wisconsin Department of Natural Resources

The Northern FHM participants meet twice yearly to determine direction and develop plans for implementing FHM. One meeting is held in the fall of each year to identify issues, concerns, and problems from the previous field season and begin initial planning for the upcoming field season. A spring meeting is held to finalize all planning for the upcoming field season. All participants are encouraged to be actively involved in the planning for Northern FHM.

Funding

Funds for the program are distributed through the Northeastern Forest Experiment Station to the appropriate state agency for detection plot activities. The off-plot aspects of the program are funded through the Northeastern Area State and Private Forestry, Forest Health Protection.

The detection plot work is funded through a 80-20 federal/state cost share cooperative agreement. The USDA Forest Service covers 80% of the costs and the state organization provides 20% of the costs. The state costs do not need to direct funds, but can be the use of equipment, reduction in overhead costs, or other sources. The principle agreement is with the appropriate state agency or with their designated cooperator.

The off-plot funds are also set up as a cooperative agreement with the cost share for the state agency in the first year of the program being 100%, 80% in year 2, 75% in year 3, and from then on at 50%. The focus for the off-plot funds involve the regional standardization of forest insect, pathogen, and damage surveys and the development of an annual state forest health report.

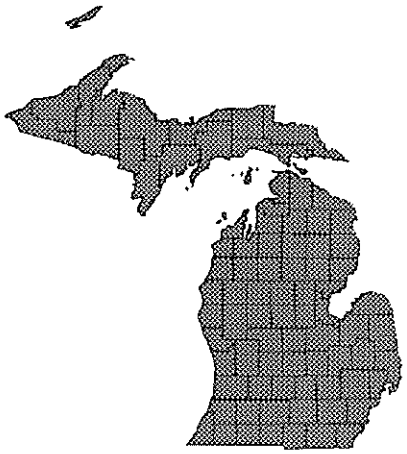
Reporting

Annual reports are developed summarizing the results from the detection plots. Reports summarizing the detection plot results from 1990, 1991, 1992, and 1993 are available. In addition, forest insect, pathogen and damage information is summarized in annual forest health reports for the Northern FHM region in 1991 and 1992. Copies of the reports can be requested at the address at the end of the document.

The results to date have identified over 95% of the trees on the detection plots in healthy conditions. In addition, there is no evidence of any regional decline. The detection plot system was sufficiently powerful to detect regional eastern hemlock-spruce defoliation in 1992 associated with the hemlock looper outbreak in Maine.

For more information about the Northern FHM Program or copies of various reports, please contact Northeastern Forest Experiment Station or Northeastern Area FHM Coordinators at:

USDA Forest Service
Forest Health Monitoring
5 Radnor Corp. Ctr., Suite 200
PO Box 6775
Radnor, PA 19087-8775
(610) 975-4035



1994 Forest Health Report: Gypsy Moth

POST-SPRAY EVALUATION OF THE MICHIGAN COOPERATIVE GYPSY MOTH SUPPRESSION PROGRAM IN 1994

T. Davis (MSU) and D. Smitley (MSU)

Thirty counties and the Michigan Department of Natural Resources participated in the Michigan Gypsy Moth Cooperative Suppression Program in 1994. All counties and the MDNR submitted postspray defoliation data. In addition, Midland County submitted a report even though they did not cost share their program this year due to the reduced amount of acres treated. All of the sample sites were evaluated in July by comparing untreated woodlots with sites treated for gypsy moth suppression. All sites were treated according to the guidelines of the Suppression Program. *Bacillus thuringiensis* was applied as Dipel 6AF (Abbot Laboratories) or Foray 48B (Novo Nordisk).

The treatment blocks were typically 20-60 acres in size. Each block sampled for defoliation represents approximately 1000 treated acres in any particular county. A maximum of 10 sample sites was requested of any county even if the number of treated acres exceeded 10,000. The sample sites were designated from the "load sheets" (pilot logs) that were filled out at the time of application by representatives of the county, contractor and Michigan Department of Agriculture. These load sheets track the acreage treated by an individual aircraft on a single day of treatment. The number of sites to be sampled by each county was determined prior to the evaluation based on the number of acres treated per load sheet. The actual sample location was left to the county coordinator to select. At each location percent defoliation was estimated for 20 oak or poplar trees. After evaluating the site that had been sprayed, a nearby site (20 more susceptible trees) of similar forest type and gypsy moth pressure was evaluated for comparison. The defoliation of all of the trees in a site was averaged. An average per county of the treated and untreated sites was calculated. Table 1 contains the data from the Michigan 1994 program.

The objective of the Michigan Suppression Program is to prevent more than an average of 40% defoliation in the susceptible trees in a treated woodlot. By that definition, the Michigan program was 98.2% successful this year. However, less than 40% defoliation also occurred in 92.3% of the untreated blocks. Gypsy moth populations are collapsing in most of the central and northeastern areas of the state. Only Ottawa, Muskegon, Oceana, Manistee and Wexford counties had any significant amounts of defoliation this year (Table 1). There are a number of factors impacting this collapse.

It was very difficult to see much impact of natural enemies several years ago. When gypsy moth began to build up in an area, it quickly reached damaging levels because the natural enemies that keep the population in check did not exist. But as each year has gone by, an increase in predator and parasite activity has been evident. As the gypsy moth population reaches its peak levels in an area (they eat all available food), they become stressed from starvation, predators, parasites and diseases. The following year the population collapses. The natural enemy population also falls off but maintains a level that allows it to heavily impact the gypsy moth population the next time it begins to build up again. This means that as the gypsy moth population builds it will never reach the levels or cause the kind of damage seen during its first peak. There will be future outbreaks, but they will tend to be spotty and will not last as long in a particular area before natural enemies will catch up with the outbreak and knock it back to a low level. It will be much trickier to find these locations in the future and will require trained, seasoned county coordinators to keep on top of local outbreaks.

The gypsy moth outbreak in Michigan is beginning to wane (Table 2). The severe winter of 1994 may have contributed to population declines in most areas of the state. The only counties that continued to see a population buildup were located adjacent to Lake Michigan. These counties were protected from some of the extremes in temperature that most of the state experienced due to the "lake effect." Overall, gypsy moth population densi-

ties and damage to Michigan forest continues to decline.

Table 1. Gypsy Moth Defoliation in Spray Blocks and Nearby Control Blocks in the 1994 Michigan Cooperative Gypsy Moth Suppression Program.

County	Pairs of Sites	Treated % def.	Untreated % def.
Alcona	2	0.6	3.6
Antrim	1	0.4	0.8
Arenac	7	16.0	18.3
Bay	1	5.9	8.3
Cheboygan	4	5.3	5.2
Clair	10	11.8	25.0
Crawford	2	2.4	6.9
DNR	7	5.5	9.6
Genesee	1	3.1	8.3
Grand Traverse	10	4.4	14.2
Iosco	8	9.5	17.2
Isabella	2	5.0	5.5
Kalkaska	4	0.1	0.6
Lake	2	5.8	22.0
Macomb	1	11.8	18.8
Manistee	1	38.5	91.0

County	Pairs of Sites	Treated % def.	Untreated % def.
Mecosta	4	5.4	10.1
Midland	3	0.8	0.9
Missaukee	1	3.6	5.5
Montmorency	3	1.8	5.9
Muskegon	6	26.7	32.9
Oakland	3	7.5	17.3
Oceana	6	16.4	52.9
Ogemaw	7	0	0
Osceola	4	2.3	7.0
Oscoda	10	0.9	3.9
Otsego	6	2.1	5.5
Ottawa	2	12.2	26.3
Roscommon	10	8.5	13.8
Tuscola	1	12.0	17.0
Wexford	2	20.8	54.5

Table 2. Percent Defoliation in Unsprayed Sites 1990-1994.

	1990		1991		1992		1993		1994	
County	# sites	% def.	# sites	% def.	# sites	% def.	# sites	% def.	# sites	% def.
Alcona	2	80.8	-	-	-	-	2	37.1	2	3.6
Antrim	-	-	-	-	-	-	1	13.0	1	0.8
Arenac	3	49.3	10	27.0	1	40.9	7	30.6	7	18.3
Bay	3	53.2	10	59.09	8	16.0	4	6.6	1	8.3
Cheboygan	-	-	-	-	-	-	10	40.4	4	5.2
Clare	10	51.9	10	59.0	12	36.9	10	33.8	10	25.0
Crawford	-	-	3	73.0	7	74.9	6	31.7	2	6.9
DNR	-	-	-	-	-	-	23	32.5	7	9.6
Genesee	-	-	2	80.0	1	5.8	1	11.5	1	8.3

Table 2 Cont'd. Percent Defoliation in Unsprayed Sites 1990-1994.

County	1990		1991		1992		1993		1994	
	# sites	% def.	# sites	% def.	# sites	% def.	# sites	% def.	# sites	% def.
Gladwin	8	65.8	13	54.0	11	42.9	10	28.9	-	-
Grand Traverse	-	-	-	-	-	-	9	64.2	10	14.2
Huron	3	73.7	3	52.0	3	8.6	1	10.3	-	-
Iosco	7	77.6	8	76.0	10	46.2	10	17.9	8	17.2
Isabella	-	-	3	45.0	2	10.5	4	30.0	2	5.5
Kalkaska	-	-	-	-	-	-	3	35.3	4	0.6
Lake	-	-	-	-	-	-	10	50.2	2	22.0
Macomb	-	-	-	-	-	-	-	-	1	18.8
Manistee	-	-	-	-	-	-	2	75.3	1	91.0
Mason	-	-	-	-	-	-	4	85.1	-	-
Mecosta	-	-	5	59.0	5	54.8	3	22.3	4	10.1
Midland	10	53.8	10	40.0	24	10.5	8	6.5	3	0.9
Missaukee	3	87.4	6	86.0	3	65.7	-	-	1	5.5
Montcalm	10	54.1	3	63.0	-	-	-	-	-	-
Montmorency	-	-	-	-	-	-	10	30.2	3	5.9
Muskegon	-	-	-	-	-	-	-	-	6	32.9
Newaygo	-	-	-	-	2	66.8	-	-	-	-
Oakland	-	-	-	-	-	-	-	-	3	5.9
Oceana	-	-	-	-	-	-	2	52.9	6	52 9
Ogemaw	3	98.2	10	42.0	-	-	8	1.5	7	0.0
Osceola	9	83.8	3	26.0	6	11.2	4	32.1	4	7.0
Oscoda	-	-	2	77.0	1	-	9	24.6	10	3.9
Otsego	-	-	-	-	9	43.2	10	39.9	6	5.5
Ottawa	-	-	2	11.0	-	-	2	61.3	2	26.3
Roscommon	-	-	10	82.0	14	48.7	10	52.2	10	13.8
Saginaw	3	65.5	-	-	-	-	-	-	-	-
Shiawasee	-	-	1	10.0	-	-	-	-	-	-
Tuscola	-	-	2	72.0	2	20.1	1	4.8	1	83.0
Wexford	2	8.5	4	61.0	8	68.5	7	38.4	2	54.5
Mean		**64.24**		**56.02**		**36.47**		**34.03**		**15.78**

INTRODUCTION AND ESTABLISHMENT OF *ENTOMOPHAGA MAIMAIGA* IN MICHIGAN

D. R. Smitley (MSU), L. S. Bauer (USDA-FS), A. E. Hajek (Cornell Univ.), F.J. Sapio (MDNR) and R. A. Humber (USDA-ARS)

INTRODUCTION *Entomophaga maimaiga* Humber, Shimazu & Soper is a virulent fungal pathogen of gypsy moth, *Lymantria dispar* (L.). In Japan, this relatively host-specific pathogen is important in the natural regulation of gypsy moths, causing extensive epizootics (Koyama 1954, Sato and Takamura 1975, Takamura and Sato 1973). In an early effort to suppress expanding gypsy moth infestations in North America, caterpillars infected with *E. maimaiga* were collected in Japan and released at several locations near Boston in 1910-11 (Speare and Colley 1912). Despite several surveys from 1911 to 1989, no infected larvae were recovered (Speare and Colley 1912, Campbell 1963). Establishment of *E. maimaiga* in North America from the 1910-11 introductions was presumed a failure (Soper et al. 1988, Hajek et al. 1990). Interestingly, in 1989, *E. maimaiga* was discovered causing widespread gypsy moth mortality throughout Massachusetts, Connecticut, southern New Hampshire and Vermont, eastern Pennsylvania and New York, and northern New Jersey (Andreadis & Weseloh 1990, Hajek et al. 1990). Research on the introduction of this fungus in North America is summarized in a recent review by Reardon and Hajek (1993).

Based on reports of epizootics in eastern states we believed that introduction of *E. maimaiga* into Michigan would help mitigate defoliation caused by gypsy moth in the future. Therefore, in 1991 and 1992 we initiated a study to compare two field introduction methods for *E. maimaiga;* relocating soil containing *E. maimaiga* resting spores from Massachusetts to Michigan, and releasing inoculated larvae onto the boles of trees. We also dispensed soil containing resting spores around the base of a single tree at 20 additional sites in 1991.

In this report we describe the results of work from 1991-1994 on the establishment and spread of *E. maimaiga* in Michigan.

RESULTS In 1991, late instar gypsy moth larvae were sampled and diagnosed for infections of the pathogenic fungus, *Entomophaga maimaiga,* and for gypsy moth NPV (nucleopolyhedrosis virus) at 50 sites in Michigan. Approximately 1500 larvae were collected and reared from these sites, and no infections of *E. maimaiga* were detected (Table 1). Apparently *E. maimaiga* was not established in Michigan when we introduced it in 1991. We tested the efficacy of two inoculative-release methods for *E. maimaiga* in replicated plots at two research sites by 1) relocating soil containing *E. maimaiga* resting spores from

Table 1. Incidence of *E. maimaiga* and gypsy moth NPV at 50 sites in Michigan surveyed in 1991. Thirty larvae (III-V) were sampled at each location.

County	Number of locations sampled	Percent larvae infected with NPV[1]	Percent larvae infected with *E. maimaiga*
Midland	10	36.4 ± 17.4	0
Clare	10	39.4 ± 18.0	0
Gladwin	6	29.2 ± 10.1	0
Arenac	4	30.3 ± 15.4	0
Gratiot	2	45.0	0
Saginaw	1	69.0	0
Osceola	4	46.8 ± 15.3	0
Missaukee	3	39.0 ± 1.7	0
Lake	4	14.8 ± 6.2	0
Wexford	6	26.5 ± 17.1	0

[1]Mean ± standard deviation.

Massachusetts to Michigan or 2) releasing inoculated larvae onto the boles of trees. Post-treatment sampling in 1991 showed that *E. maimaiga* was established in plots that received the inoculated larval treatment only. However, by 1992 establishment of *E. maimaiga* was confirmed for both inoculation methods, and there were no significant differences between the level of infection achieved by the two release methods. In addition, by 1992, infection was detected at low levels in the control plots (0.5 to 2.4%) which were located 53 m away from the treatment plots.

In 1992, a third research site was added to the study where *E. maimaiga* was introduced by relocating soil containing resting spores. Post-treatment sampling of that site in 1992 indicated a low level of establishment (5.5% infection).

Continued monitoring of fungal establishment during the 1993 season, revealed that epizootics of *E. maimaiga* occurred at the three research sites, with the incidence of infection ranging from 20 to 99% in both the treated and untreated plots. Differences in infection levels between sites were correlated with the precipitation totals for two weeks or the hours of relative humidity $\geq$90% for the 10 days that preceded larval sampling. In 1993, egg mass densities at the introduction point averaged 3 to 10-fold lower than at 300 m away (Table 2). In 1993, we also monitored the establishment and spread of *E. maimaiga* at 20 additional sites where resting spore-contaminated soil was introduced in 1991 around the base of a single tree. *E. maimaiga* establishment was confirmed in six of seven release sites where larvae or cadavers were found in 1993, and at these sites, cadavers with resting spores were consistently found 0.8 km from the introduction point (Table 3). At the the Grand Traverse County research site in 1993, plots located close to where *E. maimaiga* was introduced had the greatest level of infection and the least amount of defoliation (20 to 40%), while plots farther away had lower levels of *E.maimaiga* infection and greater defoliation (35-80%) (Figure 1). In 1994, the impact of *E. maimaiga* on gypsy moth populations was apparent by the reduced number of live larvae found near the introduc-

Table 2. Gypsy moth egg masses per 0.4 ha in September of 1993 in plots where *E. maimaiga* was introduced and in plots located 53, 175, 300, and 425 m away. *E. maimaiga* was introduced in Crawford and Lake Counties in 1991 and in Grand Traverse County in 1992.

Location	n	Distance from *E. maimaiga* introduction plot (m)				
		0	53	175	300	425
Crawford County	4	28 ± 10	43 ± 25	73 ± 52	75 ± 58	—
Lake County	4	5 ± 5	5 ± 10	18 ± 24	55 ± 44	28 ± 48
Grand Traverse County	4	45 ± 24	143 ± 134	470 ± 134	443 ± 296	532 ± 167

Table 3. Recovery of *E. maimaiga* two years after introduction at the release point and 0.8 km away.

County	Percent cadavers with *E. maimaiga* resting spores and the number of cadavers collected (x)		
	At release point	0.8 km N	0.8 km S
Roscommon - 1	92 (12)	0 (12)	8 (12)
Arenac - 1	83 (12)	(0)	8 (12)
Arenac - 2	100 (12)	25 (12)	42 (12)
Kalkaska - 1	100 (12)	25 (12)	38 (3)
Kalkaska - 2	100 (12)	75 (12)	-
Roscommon - 2	100 (10)	(0)	0 (3)
Clare	0 (5)	(0)	-

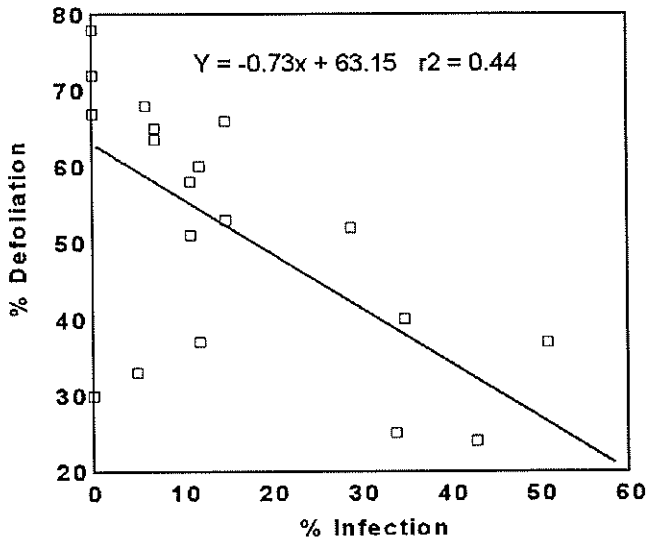


Figure 1. Relationship between percent defoliation and the proportion of larvae infected with *E. maimaiga* at research plots in Grand Traverse County in 1993.

tion point in Lake County compared with plots 500 to 2000 m away (Table 4). *Entomophaga maimaiga* has continued to spread from the introduction points at a rate that seems to double the distance away from the introduction point each year.

In 1994, *E. maimaiga* was detected 8 km away from the points where it was introduced in 1991 (Table 5). This research suggests that *E. maimaiga* will spread rapdily across Michigan over the next five years, and will help regulate gypsy moth populations at lower levels.

Literature Cited

Andreadis, T. G. and R. M. Weseloh. 1990. Discovery of *Entomophaga maimaiga* in North American gypsy moth, *Lymantria dispar*. *Proc. Natl. Acad. Sci.* U.S.A. 87: 2461-2465.

Campbell, R. W. 1963. The role of

Table 4. The number of gypsy moth larvae collected in 10 minutes and the proportion of larvae infected with *E. maimaiga* (x) at research plots in Lake County in 1994.

Distance (m)	Gypsy moth larvae		
	16 June	29 June	13 July
0	4 (0)	1 (0)	7 (28)
500	18 (0)	7 (0)	7 (0)
1000	27 (0)	11 (0)	6 (17)
2000	131 (4)	86 (1)	1 (0)

Table 5. The number of cadavers containing *E. maimaiga* resting spores found in 10 minutes of searching on August 2, 1994 at the research sites where *E. maimaiga* was introduced and at 0, 2, 4, and 8 km away from the introduction point.

Distance (km)	Lake County	Crawford County	Grand Traverse County
0	0	0.25	0
2	2.5	2.5	5.5
4	7.5	0.5	1.0
8	1.0	1.5	2.3

disease and desiccation in the population dynamics of the gypsy moth. *Can. Entomol.* 95: 426-434.

Hajek, A. E., R. A. Humber, J. S. Elkinton, B. May, S. R. A. Walsh & J. C. Silver. 1990. Allozyme and restriction fragment length polymorphism analyses confirm *Entomophaga maimaiga* responsible for 1989 epizootics in North American gypsy moth populations. *Proc. Natl. Acad. Sci.* U.S.A. 87: 6979-6982.

Koyama, R. 1954. Two epizootic diseases of the gypsy moth. *Shinrin-Boeki* 27: 296-298. [In Japanese].

Reardon, R. & A. Hajek. 1993. *Entomophaga maimaiga* in North America: A review. USDA Forest Service NA-TP-15-93.

Sato, H. & N. Takamura. 1975. Damage degree of the larch trees and an epizootic disease in the outbreak population of the gypsy moth. *Transactions of the 86th meeting of the Japanese Forestry Society*, 345-346.

Soper, R. S., M. Shimazu, R. A. Humber, M. E. Ramos & A. E. Hajek. 1988. Isolation and characterization of *Entomophaga maimaiga* sp. nov., a fungal pathogen of gypsy moth, *Lymantria dispar*, from Japan. *J. Invertebr. Pathol.* 51: 229-241.

Speare, A.T. & R.H. Colley. 1912. The artificial use of the brown-tail fungus in Massachusetts, with practical suggestions for private experiments and a brief note on a fungus disease of the gypsy moth caterpillar. Wright and Potter. Boston 31 pp.

Takamura, N. & H. Sato. 1973. Observation on the epizootic of an Entomophthorales disease in the outbreak population of the gypsy moth. *Transactions of the 84th Meeting of the Japanese Forestry Society*, 353-357.

THE USE OF COLOR AERIAL PHOTOGRAPHY FOR ESTIMATING HOMOGENEITY OF DEFOLIATION LEVELS AND STAND COMPOSITION IN GYPSY MOTH DEFOLIATED FORESTS

A. Stubblefield (U of M), J. Witter (U of M) and R. Mech (MDNR)

The objective of this study was to evaluate the precision and accuracy of aerial photographs for detecting percent levels of gypsy moth defoliation in oak and aspen stands. Twenty-two oak and aspen stands on state and federal land in northern lower Michigan were chosen for study. Ground reference data was taken from two 0.08 ha plots in each stand. These stands were photographed at peak defoliation in July 1993 by personnel from the U.S. Forest Service, State & Private Forestry, St. Paul, Minnesota. A 9 x 9 in. CIR camera (229 mm) was used with a 305 mm focal length and 60% overlap. Eight stands were flown at a scale of 1:8,000 and 14 stands at 1:4,000. The results showed a high degree of precision between both aerial estimates of defoliation and preferred host species composition and the corresponding ground reference data (Fig. 1 and 2). The pattern of results from photo estimates tended to be somewhat lower than ground estimates, especially in oak stands at higher levels of defoliation. A homogeneous distribution of defoliation and species composition was found for the majority of forest stands. Allowable error calculations indicated that four 0.08 ha photo plots are adequate for assessing defoliation and percent preferred host species for most stands.

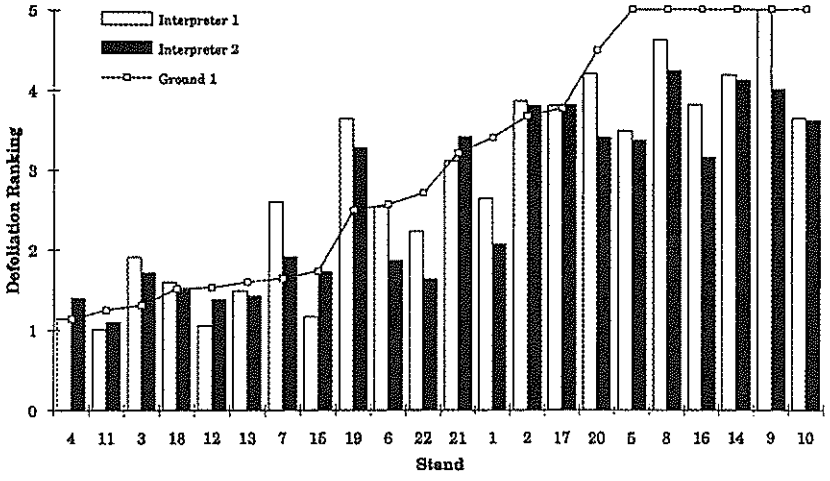


Figure 1. Defoliation estimates for Interpreter 1, Interpreter 2, and ground reference data. Defoliation ranks: 1 = 0-20% defoliated, 2 = 21-40%, 3 = 61-80%, and 5 = 81-100%.

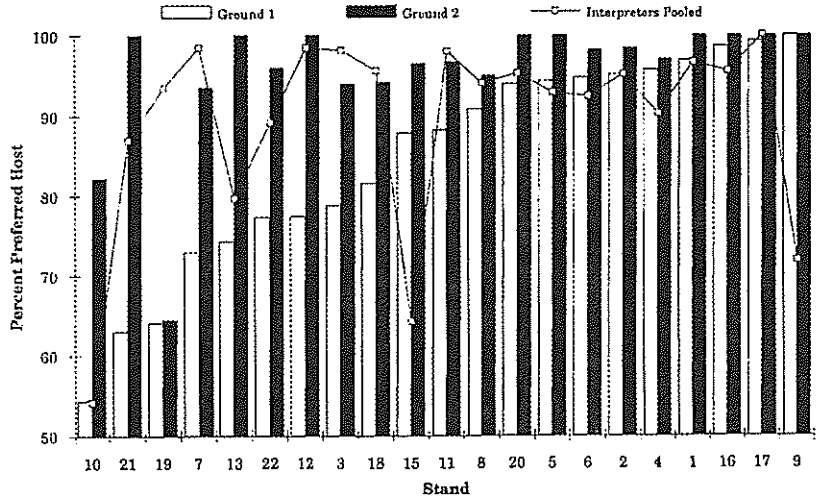


Figure 2. Percent preferred host estimates for photo interpretation and ground reference data. Ground 1 = percent preferred host estimates made from ground reference data including only dominant, codominant and intermediate trees. Ground 2 = percent preferred host estimates including only dominant and codominant trees.

THE 1994 RELEASE OF THE PREDATORY BEETLE *CALOSOMA SYCOPHANTA* (COLEOPTERA: CARABIDAE) AGAINST THE GYPSY MOTH IN MICHIGAN

T. Ellis (MSU), F. Stehr (MSU), and D. McCullough (MSU)

Introduction

Since 1991, Dr. Fred Stehr has been working with Dr. Ron Wesoloh of the Connecticut Agricultural Experiment Station to obtain *Calosoma sycophanta* adult beetles for release at two sites in Michigan against gypsy moth.

On June 18, 1994 approximately 100 beetles were released at each of two sites. One site was located in Roscommon County, the other in Ingham County.

According to Weseloh, "*Calosoma sycophanta* is a conspicuous predator that is thought to be an effective natural enemy of the gypsy moth. It was imported from Europe and easily became established in New England. Although it will feed on many different caterpillars, it is only active at times and places where gypsy moth larvae and pupae are abundant, and appears to feed primarily on the gypsy moth. Thus, it is unlikely to have a significant impact on other Lepidoptera. It is a good flier, but does not disperse rapidly, and is not present at the leading edge of gypsy moth infestations."

Methods

The two sites selected characterize two different kinds of gypsy moth infestations in Michigan. One site (Ingham County) represents an urbanized area with a growing gypsy moth population not previously defoliated. The site selected has been incrementally building a gypsy moth population for 3-4 years. The Roscommon site typifies large tracts of oak-dominant forest common to the northern portions of the state. Populations in many of these areas have collapsed or are in the process of collapsing due to NPV infection and other factors. The site selected was severely defoliated prior to the gypsy moth population collapse in 1991-92. Since that time the gypsy moth population has been rebuilding.

Each site was monitored after the beetles were released. This was accomplished by placing 30 cm square burlap hiding bands on trees clustered around the release point (10) and at 10 meter intervals out to 100 meters from the release point in each of the cardinal directions (40). This same procedure was followed

for a check plot located approximately one-quarter mile from each release block.

Each block was monitored periodically until all pupae present under the hiding bands had been destroyed and all of the adult moths had emerged. Each hiding band was monitored for total number of pupae (by sex) present and total number of pupae damaged or destroyed by *C. sycophanta*. Observational notes were taken during each visit.

Conclusions

Roscommon County Site

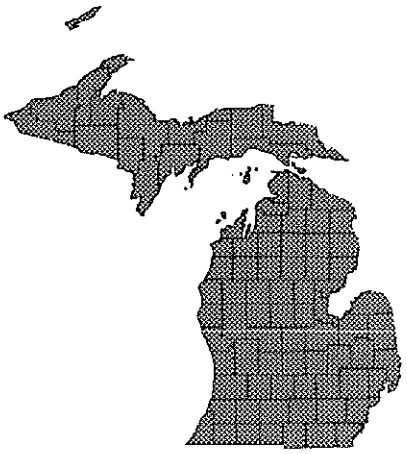
This site had a much lower gypsy moth population than first anticipated. This was due to overwintering mortality of egg masses and was exacerbated by a fairly high incidence of disease.

I never observed beetle larvae, but did find an adult beetle feeding on cherry scallop shell moth, *Hydria prunivorata* (Geometridae) caterpillars which were abundant during the time gypsy moths were pupating. Based on my observations, I would rate the success of this release as marginal.

Ingham County Site

Despite some overwintering mortality of egg masses, this site had ample gypsy moth caterpillars. The gypsy moth pupal population peaked at 7.5 pupae per hiding band.

Beetles feeding on gypsy moth pupae were extensive. In three of the four cardinal directions beetle feeding was observed 100 meters from the release point. *C. sycophanta* larvae were observed at these distances also. I would rate the success of this release as excellent.



1994 Forest Health Report: Other Insect Pests

LARGER PINE SHOOT BEETLE

R. A. Haack and R. K. Lawrence

USDA Forest Service, North Central Forest Experiment Station, East Lansing, Michigan

Detection surveys for North American populations of the larger pine shoot beetle (*Tomicus piniperda*) have continued each year since established populations of this exotic bark beetle were first discovered in Ohio in July 1992. Alpha-pinene baited traps, pine log traps, and visual examinations of pine shoots were the primary survey techniques employed by various federal, state and provincial officials in 1994. As of December 1994, pine shoot beetles had been detected in 118 counties in 6 Great Lakes states (Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York) and 10 counties in the province of Ontario (Source: National Agricultural Pest Information Service, USDA Animal & Plant Health Inspection Service, Hyattsville, MD; and Agriculture Canada, Plant Protection Division, Ottawa, Ontario).

We continued our pine shoot beetle research in 1994 with major efforts on: 1) the life history and seasonal development of the pine shoot beetle, 2) factors affecting pine shoot beetle colonization of brood hosts, and 3) the susceptibility of North American conifers to the pine shoot beetle.

The 1994 spring flight of the pine shoot beetle in Michigan began during the week of March 20-26, approximately one week earlier than in 1993. In March and April, most adults flew to potential brood hosts (recently killed pine trees, stumps, etc.) and constructed egg galleries. The adults of the next generation emerged from these brood sites in June and began an extended period of feeding in healthy pine shoots. However, at one site in southern Michigan, we observed some adults (the parent generation) tunneling in pine shoots as early as late April. Adults continued to be present in shoots throughout the spring, summer and fall, although the number of beetles in shoots was greatest soon after the brood adults emerged in June. Adult departure from shoots and movement to overwintering sites (lower trunks of pine trees) occurred primarily between mid-October and mid-November in 1994.

The results of our studies reveal several factors that affect pine shoot beetle colonization of hosts for breeding. The pine shoot beetle prefers to attack Scotch pine over most native pines, however, red pine appears to be very acceptable. Jack pine and white pine are not very attractive for breeding. For a given species of pine, trees felled as early as October are attacked at rates similar to trees felled in February. Trees felled prior to initiation of spring flight of the beetle are heavily attacked, but trees felled after flight has begun are attacked at much lower rates. The pine shoot beetle will attack the entire trunk of felled pine trees such as Scotch pine and red pine for breeding sites. The beetle avoids attacking the upper surface of logs that have been stored in full sunlight.

These results have several implications for forest management. Managers must consider all pine material cut during the previous fall, winter, and early spring as capable of supporting pine shoot beetle reproduction. This includes stumps, logs, and branches and tops with a diameter greater than about 8 cm. Managers must be especially concerned with slash created when logging Scotch pine and red pine stands, and to a lesser degree when logging in jack pine stands. Logging slash should be exposed as much as possible to direct sunlight to reduce the amount of log surface in which the pine shoot beetle will breed. In areas where the pine shoot beetle is present, managers should consider logging between May and September to avoid creating slash that will be heavily attacked by this beetle.

In 1993, we demonstrated that the pine shoot beetle was capable of breeding and shoot-feeding in several species of pines that are native to eastern and western North America. In 1994, we began a companion study to examine the suitability of some

non-pine conifers of North America (white spruce, Douglas-fir, balsam fir, and tamarack) as pine shoot beetle hosts. This study will be completed in 1995.

We are cooperating with Dr. Carol Carter and others of the Forest Service's Southern and Pacific Southwest Research Stations in a study of the genetic variability of pine shoot beetle populations. Specimens have been collected from populations in the six infested states. Genetic relatedness of the samples has been evaluated using DNA fingerprinting techniques (RAPD analysis) and isozyme analysis. Dr. Carter concludes that the pine shoot beetle populations in the United States have arisen from two founder events — i.e., one introduction having occurred in Illinois near Lake Michigan and one in Ohio near Lake Erie. Pine shoot beetle specimens are also being collected by cooperators within the beetle's native range in Europe and Asia. DNA from these specimens will be compared with the North American populations in an attempt to determine the origin(s) of the beetles introduced into North America. This information would be useful in identifying natural control agents from the beetle's native land and in determining environmental conditions with which the North American populations have evolved.

Many of the current emphasis areas of our pine shoot beetle research will be continued in 1995. Additionally, we will examine the locations of adult overwintering sites on mature red pines and Scotch pines, and factors that affect the use of pine logs as traps for detecting or reducing pine shoot beetle populations — e.g., the most effective size of log to use for trapping, and the effective distance from a beetle-infested stand at which logs will trap beetles.

YELLOWHEADED SPRUCE SAWFLY

R. K. Lawrence and R. A. Haack

USDA Forest Service, North Central Forest Experiment Station, East Lansing, Michigan

Defoliation by the yellowheaded spruce sawfly (*Pikonema alaskensis*) continued in 1994 in a black spruce provenance plantation at Kellogg Experimental Forest (Kalamazoo Co., Michigan). This was at least the third year of heavy defoliation at that site. Many trees have died during this outbreak. In 1994, about 25% of the trees did not break bud in the spring. We have been monitoring sawfly impact in this plantation since 1993 and will continue in 1995.

ASSESSING JACK PINE BUDWORM IMPACTS IN MICHIGAN'S UPPER PENINSULA

1991-1994

Robert L. Heyd (MDNR)

Jack pine budworm (*Choristoneura pinus pinus* Freeman) defoliates large acreages of jack pine (*Pinus banksiana* Lamb.) on 8- to 15-year intervals in the Lake States. The last epidemic began building in isolated areas of Michigan's Upper Peninsula in 1986-88. An unusually cold, damp spring in 1989 caused heavy mortality of young budworm larvae. By 1991 large acreages were being defoliated.

A survey tool was developed in 1991 to evaluate salvage and pre-salvage needs, and to better understand the effects of heavy budworm defoliation on the jack pine resource.

Survey Methods

Heavily defoliated, mature, well-stocked, non-storied jack pine stands were surveyed. This generally meant stands older than 50 years with basal areas greater than 80 sq. ft. per acre.

Stands were traversed at 5-chain intervals. Variable radius plots were taken every 5 chains (one plot per 2.5 acres) using a 10-factor prism. The basal area was recorded for each plot. All trees were identified to species and placed in one of two crown position categories—Dominant/Codominant or Intermediate/Suppressed. Trees were further placed into one of the following damage categories by recording the number of 8-foot sticks in the tree:

First-year damage categories:

Light — No feeding to brown cast in upper 1/2 of tree only; little or no backfeeding.[1]

Moderate — Brown cast throughout crown; backfeeding in top half of crown only.

Heavy 1 — Backfeeding in top 1/2 of crown; top of crown with few needles.

Heavy 2 — Green needles in bottom 1/2 of crown only.

Dead — No living branches.

Second-year damage categories:

Light — No feeding to brown cast in upper 1/2 of tree only; new growth throughout tree; some backfeeding in upper 1/2 of crown from previous year may be evident.

Moderate — New growth throughout tree with light brown cast; last year's backfeeding in upper 1/2 of crown evident.

Heavy 1 — New and old growth in top 1/2 of tree sparse.

Heavy 2 — Green needles in bottom 1/2 of crown only.

Dead — No living branches

[1]Backfeeding is the consumption of the previous year's needles.

Stand examiners used binoculars to refine damage category observations.

The Heavy 2 category trees represent likely mortality. Their volumes are reported as projected losses. Heavy 1 category trees represent significantly stressed jack pine, some of which may die. The proportions of resource within these two categories during and within a few years following an epidemic provide an indicator of resource condition. Top-kill was not used in damage category definitions because of differences in bud presence and viability in heavily defoliated, and even barren, upper portions of crowns.

Observation uniformity between years, between stand examiners, and between forest areas was stressed. Stand examiners were trained in both cruising technique and damage category evaluation. Examiners were encouraged to report any problems or uncertainties. The author spent a significant amount of time evaluating stands with the stand examiners.

Results

1991 Survey

This initial survey did not include a cruising volume. Trees were simply tallied within dominance and damage categories. This was the first year of widespread, heavy defoliation.

There was little mortality. The Heavy 1 and Heavy 2 categories contained 18% and 9% of the trees, respectively. Heavy 1 category trees had viable buds throughout the crown. Bud viability in Heavy 2 category trees was highly variable with most trees having many live buds. Evaluation: The resource would largely recover unless stressed by other factors such as continued budworm defoliation, drought and secondary pest problems.

1992 Survey

Fourteen stands were sampled in the Newberry Forest. Mortality averaged 1.4 ± 0.9 cords/acre, or 8% of total volume. (Total volume includes both living and recently killed trees). The average projected losses were 2.6 ± 1.7 cords/acre, or 14% of total volume. Projected losses ranged from 0 to 6.6 cords/acre, or 0 to 45% of the total volume.

1993 Survey

Newberry Forest stands were resurveyed in 1993. There was no defoliation in 1993. Mortality averaged 1.6 ± 1.4 cords/acre, or 8% of total volume. Average projected losses were 3.4 ± 1.8 cords/acre, or 17% of total volume. Mortality ranged from 0.1 to 4.5 cords/acre. Projected losses ranged from 0.2 to 9.3 cords/acre.

The Ishpeming Forest was severely defoliated for the first year. Eighty-one plots were taken in 7 stands representing 372 acres. Mortality averaged 1.2 ± 0.5 cords/acre, or 3% of total volume. Projected losses averaged 6.6 ± 2.4 cords/acre, or 18% of total volume. Mortality ranged from 0.3 to 1.8 cords/acre. Projected losses ranged from 5.3 to 11.9 cords/acre.

1994 Survey

The Ishpeming Forest was resurveyed in 1994. Second year defoliation intensity was greatly reduced. Mortality averaged 1.6 ± 1.2 cords/acre, or 4% of total volume. Project losses averaged 0.6 ± 0.7 cords/acre, or 2% of total volume. Mortality ranged from 0.3 to 3.6 cords/acre. Projected losses ranged from 0 to 1.7 cords/acre.

No defoliation was evident in the Newberry Forest in 1994. This forest area was not resurveyed in 1994.

(Stands will be resurveyed in 1995).

1992-94 Survey Summaries

Dominant/codominant trees averaged 94% of the stand volume. The more vulnerable intermediate/suppressed trees had a higher proportion of the cordwood volume in the Moderate, Heavy 2, and Dead damage categories.

Table 1 reports the inventory data for the Newberry and Ishpeming forests. The average site index(50), basal area and cords/acre stocking reflect the differences in the jack pine resources of each area. Newberry has a much larger area of jack pine which occurs on a poorer, sandy soils. Ishpeming's jack pine resource occurs on more fertile soils with water tables often influencing moisture availability.

Figure 1 graphically displays damage category volumes from 1992 to 1993 in the Newberry Forest. There were increases in the volume of wood in the Dead and Heavy 2 categories. Heavy 1 category volume decreased. The Light and Moderate category differences were less easily distinguished in the field; thus, year to year differences are interpreted with less confidence. Additionally, the Light and Moderate categories are "non-impact" classifications in terms of tree mortality. Thus, less emphasis is placed on their interpretation.

Figure 2 graphically displays damage category volumes from 1993 to 1994 in the Ishpeming Forest. There were significant decreases in Heavy 1 and Heavy 2 damage category volumes from 1993 to 1994. A slight increase in the Dead category volume is indicated.

An important empirical observation was made during the course of these surveys. This was the re-discovery of the correlation between tree mortality and stand edges and openings. Late in this survey we began putting a note in the tally sheet margin if plots occurred at a stand edge or opening. These observations were not standardized, and are here reported because of the reliability of this observation throughout the course of this survey. Tree mortality was significantly associated with stand edges and openings.

Table 1. Inventory Statistics by Forest.

Forest Area	# of Stands	# of Plots	Acres	Age	Site Index	Basal Area	Cords/Acre
Newberry	14	313	800	64 ± 7	50 ± 4	94 ± 19	21 ± 6
Ispheming	7	81	372	66 ± 5	61 ± 3	114 ± 18	38 ± 7
Totals	21	394	1172				

Figure 1. 1992-93 Newberry Forest Area Damage Comparison

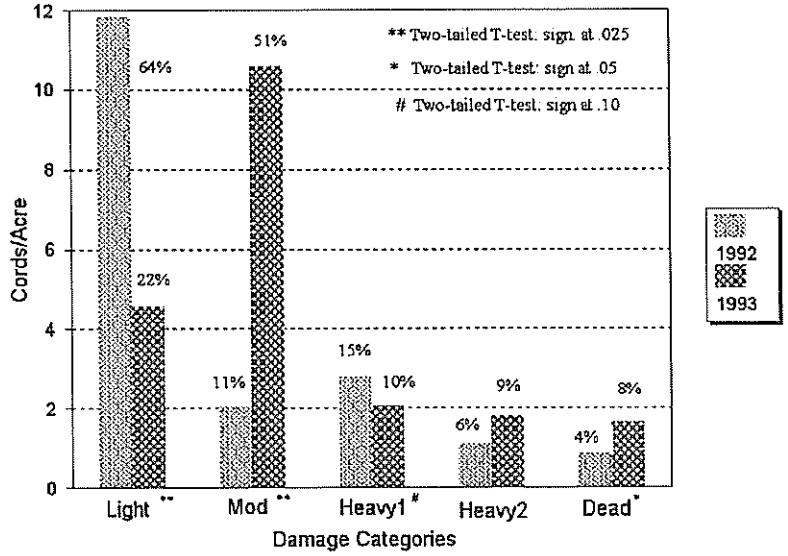
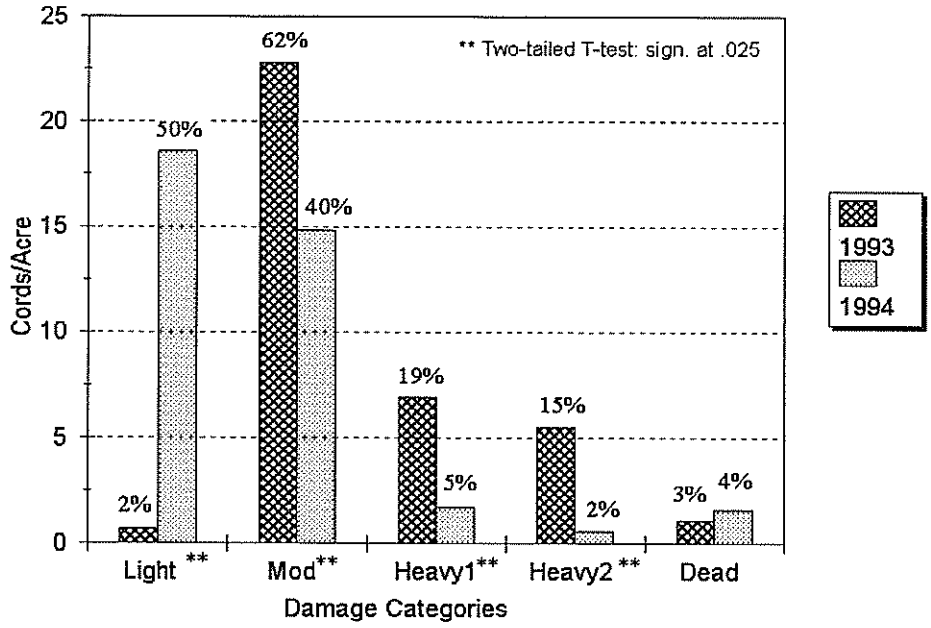


Figure 2. 1993-94 Ishpeming Forest Area Damage Comparison



Discussion

Impact studies were conducted at the end of Michigan's 1970 to 1975 jack pine budworm epidemic (Mosher, 1975). Twenty-four permanent impact plots were established in the northern Lower Peninsula in heavily defoliated jack pine. Tree mortality averaged 2.5 cords/acre, ranging from 0 to 7.6 cords/acre. This represented 14.7% of the total volume, ranging from 0 to 45%. Regressions of mortality and stand age, site index or stocking revealed no correlation between mortality and stand age or site index. However, tree mortality decreased as stocking increased. The following regression (R= -.47881) was produced: % Mortality = -.38 (sq.ft. of Basal Area) + 43.

Mosher also found the average merchantable heights of living trees was significantly greater than that of top-killed or dead trees.

The 1992-93 Newberry Forest data is comparable to Mosher's. Mortality averaged 1.6 cords/acre with a potential for 3.4 additional cords/acre of projected losses. Mortality plus projected losses ranged from 1% to 67% of stand volumes. Projected losses are 45% of this figure. Follow-up surveys will monitor what proportion of the projected losses are realized.

The Ishpeming Forest loss figures are lower than Mosher's because of the short duration of the epidemic (one year) and the highly productive sites.

The Newberry Forest experienced consecutive years of moderate then heavy defoliation. It appeared that higher mortality rates occurred in stands which where moderately defoliated the first year followed by a year of heavy defoliation. No stands were heavily defoliated in consecutive years. Heavy defoliation was generally followed by a year of light to no defoliation.

Management Recommendations

Jack pine is more resistant to recurring jack pine budworm epidemics in well-stocked stands. The ratio of stand area to stand edge should be maximized, and openings within stands kept to a minimum. Stands should be of uniform height, not storied. Lower canopy trees have higher rates of jack pine budworm-induced tree mortality. The loss of these lower canopy trees creates openings within stands which increases vulnerability to tree mortality.

Survey Method

The primary purpose of the reported survey method was to quickly evaluate highly valued jack pine stands which were heavily defoliated by the jack pine budworm. Management was concerned with current and future losses of cordwood volume.

The advantages of cruising stands at regular intervals using temporary plots to assess tree condition and losses are several. Survey costs are low, much of the surveyed resource is walked through and observed while moving between plots, and the likelihood that the resource is represented

by the large number of plots is increased. Permanent plots provide the power of paired comparisons over time, but are time consuming, expensive, and because so many fewer plots can be established and maintained, they are less likely to represent the resource.

The primary disadvantage of a temporary plot survey is the primary strength of a permanent plot survey. The year-to-year data in a temporary plot structure have the added variability of different sampling points between years. Thus, estimates of base information such as basal area, cords/acre, and volume within damage categories are used instead of fixed values between years. Because of this weakness, we learn less about the relationships between damage categories between years. However, we may gain more accurate insights into overall resource condition as we loose precision. The jack pine resource and budworm impacts are extremely variable. Within and between stand variability in all measured parameters is high. The reported survey method may better serve management needs than a permanent plot system by better representing surveyed bud-worm impacts in a diverse jack pine resource.

Reference

Mosher, D.G. 1975. *Jack Pine Budworm Impact Survey: Preliminary Report: 1975.* Unpubl. Rep. avail. from For. Mgmt. Div., Michigan Dept. of Natl. Res. (contact R.L. Heyd).

1994 Forest Health Report: Other Disease and Pest Problems

INTRODUCTION OF A BIOLOGICAL CONTROL TO MANAGE CHESTNUT BLIGHT IN MISSAUKEE COUNTY, MICHIGAN

D. W. Fulbright (MSU), S. D. Linderman (MSU) and W. J. Mahalak (MDNR).

The American chestnut tree *(Castanea dentata)* was one of the most valuable hardwood species in the eastern North American forest and represented up to 25% of the tree species in parts of its natural range. The most northwest portion of its native range extended into southeast Michigan where it was frequently found in localized areas. Owing to the tree's value in wood and nut production, pioneer orchardists made plantings of chestnut in the central and western part of Michigan's Lower Peninsula in the 19th and early 20th centuries. Some of these plantings have naturalized, yielding small stands of chestnut which appear to successfully compete with native tree species (Paillet and Rutter, 1989).

Chestnut blight, a fungal pathogen that causes cankers and girdling of the stems and trunks of chestnut, ravaged the American chestnut tree after the fungus was accidentally introduced to North America from Japan at the turn of the century. It has been estimated that 3-4 billion individual trees were destroyed by chestnut blight (MacDonald and Fulbright, 1991). The tree was protected from extinction by its propensity to produce sucker sprouts from old roots. The suckers ultimately contract blight, continuing the disease cycle. While American chestnut germ plasm is not uncommon in eastern North America, finding two mature chestnuts close enough to cross pollinate is rare.

In 1927, chestnut blight was first found in Michigan on native and planted American chestnut in the southern tier counties. From that point it spread north and has infected most stands of American chestnut in the state (Baxter and Strong, 1931). There are a few stands and individual trees that have escaped infection around the state, but each year fewer of these are left so that most of the American chestnut stands are or will be infected soon.

Interest in the American chestnut was rejuvenated in the early 1980's when it was discovered that American chestnut in some of these infected stands were surviving in spite of chestnut blight infection (Brewer, 1982). Some of the trees in these stands have been blighted for over 50 years. Where these trees once had lethal bark infections (cankers) leading to death of trunks and branches, the current situation suggests that the disease is not progressing and that the trees are surviving and reproducing. Massive amounts of wound callus produced by the tree at the edges of the cankers in response to the blight fungus results in the compartmentalization and exclusion of the fungus from the vascular cambium allowing for the tree's survival (Fulbright, et al., 1983). This recovery scenario appeared similar to that described in Europe where European chestnut (*Castanea sativa*) forests were recovering from the accidental introduction of blight from North America in 1932 (Heiniger and Rigling, 1994).

Researchers found that the hypovirulent chestnut blight fungus was infected by a virus that reduced the pathogenic characteristics (virulence) of the pathogen. It was also shown that hypovirulent strains could be applied to cankers in order to obtain control of the infection. The cankers treated with hypovirulent strains would appear very similar to the cankers that appeared in the recovering stands of Michigan's American chestnut trees. Currently, it is thought that the virus (actually a group of viruses; the Michigan viruses not readily related to the European viruses) moves from the hypovirulent strain to virulent strains ultimately reducing the virulence of the pathogen population within a chestnut stand. In this manner, it is thought that hypovirulence naturally controls chestnut blight in the recovering chestnut stands in Michigan and in Europe.

A stand of American chestnut trees originating from an early 1900's

planting in Missaukee County escaped chestnut blight infection until the late 1980's. Chestnut blight has been isolated from the stand and no indication of hypovirulent strains has been observed (Table 1). So far, the main trunks of five large trees have been killed by the disease. While the stand has not yet been entirely mapped, we have numbered over seventy trees (>2 cm dbh), including 13 trees >50 cm dbh. When all the trees are finally found and mapped (not including seedlings), we estimate there will be close to 200 trees (>2 cm dbh) with another 500 to 1000 young seedlings. Adjacent private lands to the north and east include several more large trees (>50 cm dbh) and dozens of smaller trees and seedlings.

Twenty-four of the seventy trees on the DNR land showed signs of blight in 1994. Bark samples taken from 19 trees yielded 28 isolates of blight fungus as some trees had multiple cankers. A few trees had cankers too high to sample. The blight fungus is sexually reproducing indicating that at least two different strains are present, A and a. In another test, evidence exists for the presence of 3 blight strains. This is based on vegetative compatibility (VC) data where isolates are determined to be similar or different based on a test where similar VC types when grown together will fuse and form one thallus and different VC types form a barrier (barrage) between them. This is important to know because VC types can interfere with the transfer of the virus from one strain to another effectively blocking the success of hypovirulence to disseminate in a stand of chestnut trees.

The VC testing of all strains from the Missaukee County site shows the population is comprised of three vegetative compatibility groups (Table 1). One group of six isolates was obtained from a cluster of four trees (4A, 5A, 5B, 5C) in the northeast section near the property line between the private and DNR-owned tract. The second group which is represented by only one isolate was found on one tree (34) toward the back (west) of the property. The third VC group was the largest. Twenty-one isolates recovered from 14 trees (33, 35, 37, 43, 44, 45, 46, 47, 48, Cut 4, NOS 1, NOS 2, NOS 3, NOS 4) ranging from the west/northwest end of the DNR-owned land over the property line onto the trees in the private land.

To introduce hypovirulence into this stand, we are transferring in the laboratory the virus from a hypovirulent fungus from Grand Haven, Michigan (GH2) into each virulent isolate from Missaukee County. Each virus-containing isolate, said to be "converted" will be placed back on the exact tree and canker from where it was originally obtained. The conversion of the Missaukee County isolates is verified by extraction and electrophoresis of double-stranded RNA (dsRNA), the genome of the virus. The second (single isolate) and third compatibility groups mentioned above were converted in 1994. The first VC group proved to be more difficult but was completed in early 1995.

Table 1. Characteristics of isolates from Missaukee County chestnut stand.

	VC Type	Virus	Virulence Rating
Virulent Isolates			
4A-1	1	—	71.3
5A	1	—	80.7
37-2	3	—	82.7
44-2	3	—	86.3
47	3	—	82.0
48-2	3	—	88.7
NOS1	3	—	81.0
Hypovirulent Isolates*			
GH2	2	+	50.0
34 (GH2)-1	2	+	50.7
37-2 (GH2)	3	+	54.3

Virulence (or aggressiveness) of the isolates before and after conversion was tested by inoculating apple fruit with the pathogen and measuring the growth of the lesions. While apple is not a normal host for the pathogen, the rate of growth through the apple fruit can give a measure of the aggressiveness of the isolates. Lesions on the apple by the converted hypovirulent strains were consistently smaller than the original virulent isolates. For example, in Table 1 it can be seen that the Missaukee County isolates are reduced in virulence when the GH2 virus is transferred to them.

In late summer 1994, hypovirulent cultures representing the two VC groups converted in 1994 were taken back to the DNR-owned tract for canker inoculation. Two chestnut trees with cankers ramifying the entire bole were punch inoculated around the trunk about breast height. Leather punches were used to remove bark and the fungus was inserted and covered by tape. Two basal sprouts per tree were also inoculated by slicing the thin bark and inserting the fungus. The intersection between the trunk and the sprouts was also punch inoculated in a ring. Both trees then had open petri dishes of the hypovirulent strain attached around the trunks to allow dissemination of the spores. Tree 34 was inoculated with hypovirulent isolate 34(GH2)-5 and Tree 37 was inoculated with 37-2(GH2). Tree 34A, a healthy tree, was punch inoculated with both hypovirulent strains to determine the response of a healthy tree to the hypovirulent inoculum and to determine the prophylactic ability of the hypovirulent strains.

In the spring of 1995, we hope to begin field work again by applying hypovirulent strains to all infected trees at this site and then monitoring the dissemination of the hypovirulent strains to non-inoculated trees.

Literature Cited

Baxter, D.V. and F.C. Strong. 1931. Chestnut blight in Michigan. *Mich. Agric. Exp. Stn. Tech. Bull.* No. 135.

Brewer, L.G. 1982. The present status and future prospect for the American chestnut in Michigan. *Mich. Bot. Club.* 21:117-128.

Fulbright, D.W., W.H. Weidlich, K.Z. Haufler, C.S. Thomas and C.P. Paul. 1983. Chestnut blight and recovering American chestnut trees in Michigan. *Can. J. Bot.* 61(12):3164-3171.

Heiniger, U. and D. Rigling. 1994. Biological control of chestnut blight in Europe. *Annu. Rev. Phytopathol.* 32:581-599.

MacDonald, W.L. and D.W. Fulbright. 1991. Biological control of chestnut blight: use and limitations of transmissible hypovirulence. *Plant Dis.* 75(7):656-661.

Paillet, F.L. and P.A. Rutter. 1989. Replacement of native oak and hickory tree species by the introduced American chestnut (*Castanea dentata*) in southwestern Wisconsin. *Can. J. Bot.* 67(12):3457-3469.

PREDISPOSING FACTORS INVOLVED IN RED PINE POCKET MORTALITY

C. Randall (MSU) and J.H. Hart (MSU)

Introduction

There are about 600,000 hectares of red pine (*Pinus resinosa*) forest and plantations in the Lake States, approximately one-third of which are in Michigan's northern Lower Peninsula. A substantial proportion of these stands are in plantation. Currently the red pine resource is managed for revenue from pulp wood and sawtimber. In the last decade a sustained market for red pine utility poles has increased the value of this resource in the northern Lower Peninsula.

In recent years a new disease has been shown affecting 30- to 50-year-old plantation-grown red pine on a variety of soil types in Wisconsin, Michigan and Illinois. The disease, known as red pine pocket mortality (RPPM), was first reported in 1975 and is of unknown causes. A common symptom of red pine decline is a large circular area of dead trees (pocket), ringed by trees showing reduced diameter and height growth. Dead trees and greatly increased growth of understory plants can be found in the center of the pocket.

The rate at which RPPM is spreading and the degree of crop loss has not yet been assessed in Michigan or in other Lake States. Aerial surveys during the summers of 1988 and 1989 suggested that the amount of mortality had increased significantly. An aerial survey by the U.S. Forest Service of the Huron-Manistee National Forest found 440 pockets of dying red pine. However, since the drought years of 1988-89, dramatic increases in mortality have not been observed in Michigan.

Our observations have indicated that the problem is not site specific, i.e. some pockets have developed on well drained sands whereas other pockets

have developed on poorly drained areas. Several species of insects and fungi are associated with the decline but none have been consistently present in all pockets.

It is well known that trees stressed by site conditions or weather extremes are more susceptible to insect and disease problems. Observations have indicated that the pine root collar weevil, *Hylobius radicus*, is the most consistently associated with the problem in Michigan. But many trees severely attacked by *H. radicus* are not dying, and mortality occurs in the absence of *H. radicus*. Bark beetles (*Ips pini* and *Dendoctronus valens*), and the fungal species *Armillaria,* spp. and *Diplodia*, spp. have also been observed. We believe these agents are involved in final symptom expression and are known to follow stress, but again the presence or absence of these organisms and the degree to which they contribute to the decline varies from pocket to pocket.

RPPM may be viewed as a disease of complex origin i.e. one that is caused by both primary and secondary factors. We consider the primary stress-inducing factor to be abiotic in origin, i.e. one that relates to site conditions such as the soil nutrient status. The focus of our research has been on the abiotic factors associated with the disease. Soil acidification, for example, may be the initial stress-inducing factor which predisposes red pine to insect and disease problems and to their eventual decline.

The Role of Soil Acidification

The primary abiotic factors being considered in our study are soil nutrient content and acidification. The role of acidification in forest decline has been studied globally. Soil acidification has been cited as a cause of forest growth decline by creating nutrient deficiencies through leaching of base cations (especially Ca^{2+}) and also by increasing the concentration of aluminum (Al^{3+}) in solution to toxic levels.

Soluble aluminum in sufficient concentration is directly toxic to the roots of a wide range of woody plants. Aluminum toxicity may be present in almost any inorganic soil with a pH less than 5.5 depending on the sensitivity of the plant species and the amount of organic material in the soil. Aluminum toxicity has been associated with decline of spruce in Europe where it is thought that soil acidification resulting from anthropogenic deposition in combination with natural processes mobilizes aluminum which reaches levels toxic to fine roots. Death of fine roots then leads to development of symptoms associated with reduced uptake of water and nutrients. In the United States, aluminum toxicity and calcium or magnesium deficiency due to aluminum inhibition of uptake are also being considered as causes of red spruce (*Picea rubens*) decline. Investigations of red spruce decline suggest that an imbalance of aluminum and calcium in the fine root environment leads to reduced growth rates and renders mature trees vulnerable to extant secondary diseases and insect pests (Shortle and Smith, 1988).

In the case of RPPM, anthropogenic deposition is not considered to be a major source of acidification. Instead the causes of the decline can be found in the inherent characteristics of the red pine plantation. Red pine pocket mortality is not found in natural stands. Unlike plantations, natural stands are not densely planted or even-aged. In plantations, close spacing enables root grafting and transmission of root-infecting fungi. Also a dense layer of pine litter accumulates on the forest floor as the trees mature. Pine needle accumulation over time could eventually affect soil pH as needles decompose and release humic acids into the soil. This may explain why symptoms of RPPM are not seen until the trees are mature. As the pH drops aluminum becomes more mobile and available for uptake, but more importantly it competes with the uptake of other essential nutrients, especially calcium, magnesium and potassium.

Results and Discussion

Our investigations of areas with red pine pocket mortality in Michigan revealed soils of low pH (3.9 to 5.3) where aluminum toxicity may be a problem especially in relation to inhibition of uptake of calcium and other nutrients. Research plots established in pocket decline sites near White Cloud, Michigan revealed levels of exchangeable calcium and magnesium that fell well below recommended minimum standards for red pine plantations. In addition, the molar calcium/aluminum ratios in these plots tended to be below 1.0 especially in the lower soil mineral layers. Authorities studying red spruce decline have suggested that a molar calcium/aluminum ratio below one in forested areas indicates a potentially aluminum-toxic condition (Shortle & Smith, 1988). A study of declining spruce in Germany, found that in the lower soil mineral layers, the decrease in fine root biomass correlated with decreasing calcium/ aluminum ratios (Murach and Ulrich, 1988).

In our study roots were removed from meter-square plots to a depth of 60 cm at both decline sites and healthy plantation sites. Of the volumes of fine roots (defined as roots less than 3 mm in diameter) recovered from five pocket decline sites in the Huron-Manistee National Forest, 37.1 percent were dead, versus only 1.7 percent dead fine roots recovered from two plantation check plots of healthy pines. It is thought that the fine roots are dying first leading to the symptom expression of stunted, browning needles in the crown.

Nutrient analyses were performed on soil, needle and root samples from the five disease plots and two plantation check plots in the Huron-Manistee forest, and also on three natural stand plots in the Upper Peninsula. The most interesting results were obtained from the analyses of fine roots samples. Significant differences were found between the Ca/Al, Mg/Al and K/Al ratios between fine roots in disease plots versus the two healthy plantations and the natural stand. There appears to be an increasing gradient in the ratios of calcium, magnesium, and potassium to aluminum starting from the disease plots at the edge of the decline (Disease-Edge), to within the disease plots but just outside the edge of the decline where trees appear healthier (Disease-Out), to the healthy plantation check plots nearby (Plantation Check) (Figure 1). These results indicate that inhibition of the uptake of calcium, magnesium and potassium by aluminum may be causing the death of fine roots within disease plots which would in-turn stress the trees and result in the visual symptom expression of RPPM.

Another curious observation was that manganese levels were significantly lower in fine roots in disease plots versus healthy plantations. This suggests the possibility of manganese deficiency problems—a surprising result since manganese is generally not a problem in low pH soils.

Liming decline sites would be one way to the test the hypothesis that nutrient factors related to low soil pH are causing the death of fine roots. Observations made after liming would include whether the increased soil pH results in higher Ca/Al, Mg/Al and K/Al ratios within fine roots and recovery of declining trees within pockets.

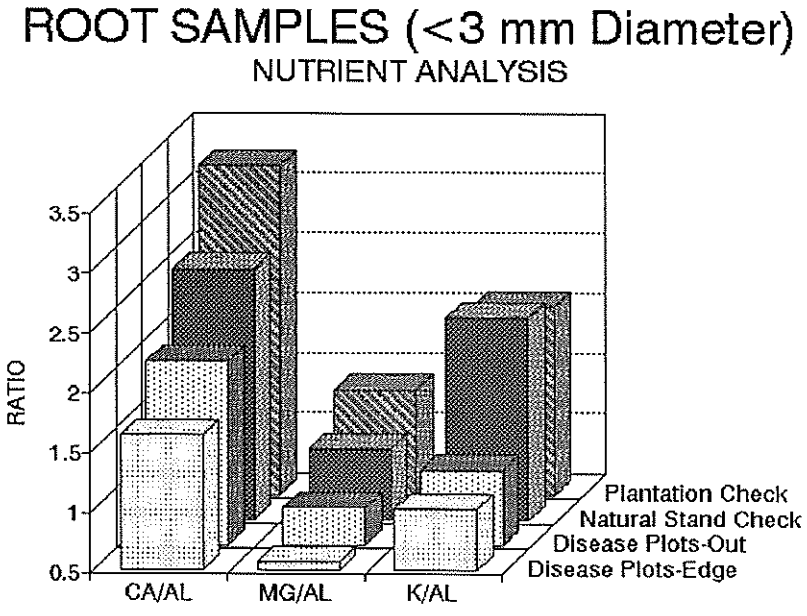
Further research on red pine pocket decline should focus on methods of controlling and/or preventing the disease. Good management practices established in plantations may prevent predisposition to RPPM. Among the planting strategies that should be considered in areas prone to RPPM are mixed plantings of red pine with other species, planting at different time intervals to produce uneven-aged stands, and/or decreasing the planting density. These practices, either alone or in combination with each other, would more closely simulate conditions found in a natural stand. Since RPPM is only found in plantations, a stand's susceptibility to the disease would be reduced.

Literature Cited

Murach, D. and B. Ulrich. 1988. Destabilization of forest ecosystems by acid deposition. *GeoJournal* 172: 253-260.

Shortle W.C. and K.T. Smith. 1988 Aluminum-induced calcium deficiency syndrome in declining red spruce. *Science* 240:1017-1018.

Figure 1. Differences in Ca/Al, Mg/Al, and K/Al ratios (Disease Plots versus Check Plots).



1994 Forest Health Report: Urban Forests

MICHIGAN STREET TREES: AN ASSESSMENT OF TWENTY CITIES - 1994

R. Wildenthal (Consumers Power, Co.) and J.J. Kielbaso (MSU)

Introduction

A Michigan street tree survey was undertaken as part of a national effort promoted by American Forests and the Michigan State University Forestry Department, to provide a quick, general assessment of the present state of Michigan's urban forests. This report summarizes the data collected for Michigan and addresses some of the conclusions that can be derived from this information. The data collected in Michigan in 1994 will added to that of 437 other cities in the national survey. The summary for Michigan is shown in Table 1.

Table 1. Summary Report for Michigan Street Tree Survey - 1994

Number of Cities in the Sample:	**20**	
Miles of Streets in the Sampled Cities:	**6,253**	
Miles of Streets in the Sample:	**84.05**	
This is a Sample Percentage of:	**1.34**	
TREE SIZE DISTRIBUTION:	**NUMBER**	**PERCENT**
Sapling: < 3 Inches	893	13.75
Small : 3-12 Inches	2,836	43.66
Medium: 12-24 Inches	2,049	31.55
Large: > 24 Inches	717	11.04
TREE CONDITION DISTRIBUTION:	**NUMBER**	**PERCENT**
Excellent Condition	1,070	16.47
Good Condition	2,233	34.38
Fair Condition	1,847	28.44
Poor Condition	1,345	20.71
SAMPLE SUMMARY:	**NUMBER**	**PERCENT**
Total Live Trees in Sample	6,495	49.05
Total Dead Trees in Sample	36	0.55
Total Empty Spaces in Sample	6,710	50.68
Total Tree Spaces in Sample	13,241	100.00
Total Live Trees in Group	483,203	49.05
Total Dead Trees in Group	501,877	50.95
Total Tree Spaces in Group	**985,080**	

Methods

City Selection

The twenty cities sampled were Ann Arbor, Battle Creek, Cedar Springs, Cheboygan, Detroit, East Lansing, Elk Rapids, Grand Rapids, Grosse Pointe Woods, Lincoln Park, Livonia, Manistee, Manistique, Pontiac, Saginaw, Sparta, Southfield, Standish, Warren and Woodhaven. In keeping with the survey process established by the team for the original project, these cities were randomly selected.

Plot Determination

Each city was divided into approximately equivalent sections to match a predetermined number of sample plots. The plots were then randomly located at central street intersections in each section. A sample plot consisted of two quarter-mile lengths originating at right angles from the intersection. A total of one mile of street was thus inventoried for each sample plot. The number of plots was predetermined, according to the American Forests project guidelines by the city population category; 24 plots for cities 250,000 and over; 10 plots for cities with populations ranging from 25,000 to 249,999; and 5 plots for cities under 25,000.

Results

The survey sampled 84.05 miles out of 6,253 total city street miles in the 20 cities. The sample percentage for Michigan is 1.34% (Table 1), which is close to the 1.22% sample percentage reflected in the national survey. At each sample plot all street trees were identified by species, and categorized by diameter and condition classes. Available planting sites were also tallied.

Urban Tree Population

The survey results are based on 6,495 live trees tallied, 36 dead trees, and 6,710 available planting spaces. This information is shown in Table 1. The relatively small number of dead trees (0.5%) suggests that dead tree removal is a task that most communities are able to accomplish. The proportionately large number of empty planting sites (50.95%) indicates that planting is not so readily accomplished. This is in common with the 436 other cities nationwide where 48.59% of available spaces are open. Money is the most probable cause determining priorities. The number of street trees in Michigan is estimated to be 1,674,032 as determined in Table 2.

Tree Size

Information was tabulated for Michigan as a whole (Table 1), and individually for the municipalities sampled (Table 3). For Michigan, in general, the dominant size category represented on streets is the 3"-12" diameter class, at 43.66%. For the other size classes, 13.75% are in the <3" sapling class, 31.55% are in the 12"-24" diameter size class, and 11.04% are in the 24"+ class. A natural forest might have 26% in saplings/seedlings, 50% in small, 15% in medium (mature), and 9% in the large size class (Boyce, 1981). The Michigan street tree population, then, consists of about half as many saplings and twice as many medium size as a natural forest, and is similar

Table 2. Number of Street Trees in Michigan Estimated by City - Size - Category.

CITY POPULATION CATEGORY	1 NUMBER CITIES SAMPLED	2 TOTAL CITIES IN CATEGORY	3 NUMBER OF TREES SURVEYED	4 ESTIMATED TOTAL TREES*
1,000,000	1	1	186,200	186,200
100,000 - 249,999	4	7	162,990	285,232
50,000 - 99,999	5	15	81,156	243,468
25,000 - 49,999	1	23	11,472	263,856
10,000 - 24,999	2	45	17,362	390,645
5,000 - 9,999	2	53	6,825	180,862
2,500 - 4,999	3	71	3,526	83,449
0 - 2,499	2	42	1,920	40,320
			ESTIMATED TOTAL IN STATE =	**1,674,032**

*Column 4 = Columns (3/1) x 2

Table 3. Tree Size Distribution Summary by City for Michigan.

CITY NAME	LIVE TREE TOTAL	% SAPLING	% SMALL	% MEDIUM	% LARGE	DIVERSITY INDEX
Ann Arbor	598	14.21	49.67	30.94	5.18	2.94
Battle Creek	251	2.39	18.73	62.15	16.73	2.50
Cedar Springs	184	11.41	28.26	41.85	18.48	2.87
Cheboygan	110	27.27	11.82	43.64	17.27	2.12
Detroit	798	5.64	59.90	21.43	13.03	2.57
East Lansing	378	13.49	37.83	39.68	8.99	2.45
Elk Rapids	140	19.29	21.43	44.29	15.00	2.69
Grand Rapids	421	15.91	40.38	39.19	4.51	2.58
Grosse Pte Woods	383	34.46	38.38	16.71	10.44	2.77
Lincoln Park	478	7.95	60.04	20.29	11.72	1.99
Livonia	403	10.92	41.19	40.20	7.69	2.59
Manistee	215	12.56	20.47	55.81	11.16	2.13
Manistique	54	9.26	16.67	53.70	20.37	1.91
Pontiac	177	20.34	14.69	56.50	8.47	1.83
Saginaw	402	5.22	29.60	49.25	15.92	2.54
Southfield	487	21.56	58.52	13.35	6.57	2.60
Sparta	98	7.14	23.47	37.76	31.63	2.27
Standish	180	8.89	30.56	46.67	13.89	1.63
Warren	379	10.03	49.34	18.47	22.16	2.03
Woodhaven	359	25.63	71.87	2.51	0.00	2.68
TOTALS	**6,495**	**13.75**	**43.66**	**31.55**	**11.04**	

for both the small pole-size and large trees.

Tree Condition

The highest percentage of trees (34.38%) are in good condition. The smallest percentage (16.47%) are ranked in excellent condition, 20.71% in poor condition, and 28.44% in fair condition (Table 1). These results can be seen, by city, in Table 4. The data also reveal that for the 24" + diameter class the majority of trees sampled are in the poor condition class (not shown). Extrapolation of these data suggests that removals are imminent statewide in a very visible size class, which will result in the majority of remaining trees being in smaller size categories. The visual impact will be significant in the communities with predominantly mature urban forests.

Tree Species

The predominant tree species found on Michigan city streets is the Norway maple (17.85, and cultivars +3.19); silver maple (16.51); green ash (8.89); sugar maple (7.63); honeylocust and cultivars (7.09); red maple (5.74); crab apple (3.32); Bradford pear (3.29); white ash (2.47); littleleaf linden (2.11); sycamores (2.09); American elm (2.06); Siberian elm (1.38); red oak (1.35); horsechestnut (1.23); and box-elder (0.93). The species diversity index estimate for Michigan is calculated at 3.05, with 91 species and cultivars having been encountered. The

Table 4. Tree Condition Summary by City for Michigan.

CITY NAME	LIVE TREE TOTAL	% EXCEL.	% GOOD	% FAIR	% POOR	% DEAD
Ann Arbor	598	27.59	27.93	25.08	19.40	0.67
Battle Creek	251	9.96	29.48	37.05	23.51	0.80
Cedar Springs	184	26.09	25.00	34.24	14.67	1.09
Cheboygan	110	5.45	10.91	29.09	54.55	0.00
Detroit	798	4.76	30.20	35.34	29.70	0.38
East Lansing	378	9.26	27.25	27.25	36.24	0.00
Elk Rapids	140	17.86	9.29	24.29	48.57	0.00
Grand Rapids	421	25.42	36.82	21.38	16.39	0.95
Grosse Pte Woods	383	48.56	30.03	16.19	5.22	0.00
Lincoln Park	478	5.44	43.51	42.89	8.16	1.05
Livonia	403	35.98	41.19	19.35	3.47	0.25
Manistee	215	6.05	15.81	27.91	50.23	0.93
Manistique	54	3.70	9.26	18.52	68.52	7.41
Pontiac	177	7.91	36.16	40.11	15.82	0.00
Saginaw	402	2.49	25.37	29.35	42.79	1.00
Southfield	487	18.28	58.52	19.71	3.49	0.62
Sparta	98	14.29	32.65	39.80	13.27	0.00
Standish	180	3.33	11.67	31.67	53.33	0.56
Warren	379	10.82	53.30	30.87	5.01	0.26
Woodhaven	359	20.89	52.37	24.23	2.51	0.00
TOTALS	**6,495**	**16.47**	**34.38**	**28.44**	**20.71**	**0.55**

national average is close to 3.0. The diversity index was calculated as in the national program, using the Shannon-Weiner formula. The Shannon Index has been used broadly as a measure of diversity of a population. In this case, it measures the degree of eveness in the street tree population along with the numbers of different species. The index should be used cautiously and is best used when comparing "similar" cities. Since the diversity index is a log function, small differences can be very significant.

Planting Needs

Determination of planting site availability is a subjective decision. To mitigate the subjectivity, the following criteria were used: the presence of at least a three-foot tree lawn, practical location regarding utilities, pedestrian access, and vehicular traffic patterns, and the existing adjacent private landscaping. On average, for Michigan, the survey results indicate the percentage of available planting sites to be 50.95% with a calculated fully stocked spacing of 33.5 feet.

The percentage of available site spanned a wide range from Manistique at 85.08% to Grosse Point Woods at 19.71%. The majority fell between 40-60%. The planting needs summaries for each city are shown in Table 5.

The number of trees planted and removed as reported by those cities having that information available are presented in Table 6. The average of the two-year data from all cities reporting this information shows a two-year trend to plant about as many trees as

are removed. When evaluating comparisons between planting and removal rates, equivalent numbers do not always lead to, or result in, a city-wide reforestation process. Casual observation showed concentrated planting efforts in conjunction with construction projects while removals occur throughout the a city. The average planting/removal ratio is shown to be 1.01. If Detroit, which dominates the data, is not included, the ratio is then 1.7. It was of interest to calculate a ratio not including the Detroit data because of the significantly greater population size and larger area covered in Detroit compared to the other cities surveyed.

Table 6 shows that plantings exceed removals. This information is encouraging. However, taking into consideration the calculated open spaces and assuming no change in the planting/removal ratio, it will still take several hundred years to reach full stocking of Michigan city streets.

Conclusion

This inventory project presents an opportunity to see how different municipalities manage their urban forest resource. In the smaller, older communities much of the existing forest is comprised of mature maples planted in the early part of this century. Without an immediate, concentrated planting effort, these communities will be faced with the loss of a substantial portion of the current street tree population over the next ten to fifteen years. The larger communi-

Table 5. Street Tree Planting Needs Summary by City for Michigan.

CITY NAME	TOTAL TREE SPACES	LIVE TREES	% LIVE	DEAD AND EMPTY	% NEED
Ann Arbor	841	598	71.11	243	28.89
Battle Creek	606	251	41.42	355	58.58
Cedar Springs	294	184	62.59	110	37.41
Cheboygan	318	110	34.59	208	65.41
Detroit	1,720	798	46.40	922	53.60
East Lansing	729	378	51.85	351	48.15
Elk Rapids	345	140	40.58	205	59.42
Grand Rapids	625	421	67.38	204	32.64
Grosse Pte Woods	477	383	80.29	94	19.71
Lincoln Park	1,049	478	45.57	571	54.43
Livonia	614	403	65.64	211	34.36
Manistee	415	215	51.81	200	48.19
Manistique	362	54	14.92	308	85.08
Pontiac	585	177	30.26	408	69.74
Saginaw	835	402	48.14	433	51.86
Southfield	1,116	487	43.64	629	56.36
Sparta	213	98	46.01	115	53.99
Standish	461	180	39.05	281	60.95
Warren	1,036	379	36.58	657	63.42
Woodhaven	600	359	59.83	241	40.17
TOTALS	**13,241**	**6,495**	**49.05**	**6,746**	**50.95**

ties share the same problem, but it is distributed over a larger area, so the impact will be felt most by the affected neighborhoods, rather than city-wide.

With almost half of the live trees (49.15%) ranked in the fair and poor condition class, and with half of the available planting sites empty, a formal tree management and planting plan appears necessary if Michigan is to maintain the continuity of urban forest cover as declining trees are removed. While plantings in conjunction with construction projects add to the overall tree population, they do not address the need for routine replacements of declining or removed trees.

Different combinations of the usual urban forest problems appeared in all communities: restricted planting areas, compacted soils, poor species/site selections, mechanical damage to lower trunk areas from motor vehicles and lawn maintenance equipment, poor branch structure from lack of corrective pruning early on, and disease and insect infestations in the large wounds resulting from removal of limbs on mature trees that should have been addressed when the trees were younger and better able to callus over the wound area.

It is hoped that continued efforts will be made in tracking the condition, stocking, and species diversity of Michigan's urban forests and that the information collected during this

Table 6. Number of Trees Planted and Removed Over Two-Year Period: 1992/93.

	1992 SEASON		1993 SEASON		TWO-YEAR
MUNICIPALITY	PLANTED	REMOVED	PLANTED	REMOVED	RATIO
Ann Arbor	850	360	900	430	2.22
Battle Creek	50	93	0	102	.26
Cedar Springs	20	5	22	6	3.82
Cheboygan	0	0	8	0	—
Detroit	290	2,515	297	1,639	.14
East Lansing	125	116	267	35	2.60
Elk Rapids	100	10	60	12	7.27
Grand Rapids	1,125	596	1,139	616	1.86
Grosse Pte Woods	96	174	176	91	1.03
Lincoln Park	50	150	50	150	.33
Livonia	680	242	540	322	2.16
Manistee	25	30	20	20	.90
Manistique	0	0	0	0	—
Pontiac	135	251	135	238	.55
Saginaw	72	93	101	179	.64
Southfield	325	60	400	45	6.90
Sparta	0	10	0	10	—
Standish	36	4	0	5	4.00
Warren	400	250	500	350	1.50
Woodhaven	150	8	165	6	22.50
TOTALS	**4,529**	**4,967**	**4,780**	**4,256**	**1.01***

*Ratio without Detroit data = 1.7

project can serve as a benchmark for future comparisons.

MANAGEMENT OF *DIPLODIA* TIP BLIGHT OF PINES

Dr. David L. Roberts, Director
MSU Plant and Pest Diagnostic Clinic

Austrian (*Pinus nigra*) and Scotch (*Pinus sylvestris*) pines have been widely planted throughout the Midwest as valuable landscape trees. Because of its salt tolerance, Austrian pine has been utilized quite effectively along highways for quite a few years. Along with Scotch and Austrian pines, mugo (*Pinus mugo*) pine has been used as a shrub planting in many highly maintained landscapes. Over the years, "tip blight", caused by *Diplodia pinea* (=*Sphaeropsis sapinea*), has become increasingly more prominent as these trees age and approach maturity. The disease has essentially reached "epidemic proportions" since many pines around the region have contracted the disease. Red pines (*Pinus resinosa*) are less susceptible unless planted in dense stands where air movement is restricted. White pine (*Pinus strobus*) is virtually immune to the disease.

Symptoms

As the disease name suggests, *Diplodia* causes a tip blight. The fungus overwinters on dead needles, bark and cones. Swollen buds and emerging shoots are most susceptible to attack by *Diplodia* as spring rains release spores from fungal fruiting structures. During periods of rainy, humid weather, spores of the fungus germinate and infect elongating candles. The shoots may not show symptoms for several weeks since the fungus slowly colonizes and girdles the shoots. Toward late June and July, the infected tips will become brown and will usually show no further viability. Disease development and severity is highly dependent upon weather conditions. The greater the moisture and wetness duration, the greater the potential for extensive disease. Many shoots may be affected, especially on the lower limbs. If left unchecked, the fungus may eventually kill whole branches.

Implementing IPM

Unfortunately, *Diplodia* tip blight is difficult to manage in an integrated manner on established trees. There are no known biological controls. Cultural controls such as pruning and maintaining good vigor may help aesthetically but will not inhibit the disease spread to any significant extent. The only and hence most effective control is fungicide treatment. While there are several fungicides registered for *Diplodia*, the benzimidazoles tend to work the best. Cleary 3336™ and Fungo 85™ are benzimidazoles which can be quite effective if used correctly. There are methods of avoiding *Diplodia* tip blight as discussed below.

Spray Timing is Absolutely Critical!!

Sprays should be applied according to label rates **at or slightly before bud break**. A failure to protect swollen buds or emerging shoots during a rainy infection period could lead to severe shoot loss and make subsequent treatments useless. In fact a landscape manager may not know whether the **first** spray was effective **until after the second or third spray**, three or four weeks later. It is a wise move to get the first spray on a little early rather than too late. Depending on the species of tree, climatic conditions and genetic variability, the first spray date may vary from late March through early May. For highly maintained, valuable trees, three or four applications spaced 10-14 days apart would be advised. The spacing of the sprays will depend upon climatic conditions; the more precipitation the closer the interval. Lower value trees may be helped with one or two sprays keeping in mind that the first spray is critical. The second spray should be applied when any extended wetting periods are expected. Please remember that sprays will not be effective if they are not permitted sufficient time to dry before precipitation. Bordeaux mix is another fungicide which can be quite effective. It is a contact chemical and may require more frequent applications compared to the systemic benzimidazoles. Bordeaux mix also tends to be abrasive to the sprayer. Some individuals have reported good control of tip blight with a couple of well timed sprays of this contact fungicide.

Patience Is A Virtue

Valuable trees which may appear severely affected by *Diplodia* may be brought back to reasonably good health with sufficient patience and effort. Check severely affected branches for viability in the bud and cambium (water conducting) tissues. If green succulent tissue is found, the branch and tree have a chance.

Several years of persistent spraying and quality care may help affected trees to recover and appear as fine looking specimens.

Alternative Methods of Dealing with *Diplodia*

Each year, I am encountering more individual homeowners and businesses who want low maintenance (read: less pesticide treatments) plants for their landscapes. Some of them are incredulous that nurseries would sell and that landscapers would install Scotch and Austrian pines which require more frequent pesticide usage. I believe it is our responsibility to inform the public that while Austrian pines make beautiful landscape trees, they are also more susceptible to diseases and insects. In other words, we need to provide the public with alternatives if practical. Many individuals will prefer Austrian and Scotch pines regardless of the problems and subsequent maintenance.

Alternative plants: *Diplodia* tip blight is most severe on the introduced exotic pines, Scotch and Austrian. Native pines have less severe problems with this fungal disease. Red pine is somewhat susceptible while white pines are immune. With fewer pests and diseases attacking the native plants, we can expect fewer pesticide treatments and less maintenance with native pines than with the "exotic" pines.

Limited-Life Trees: Austrian and Scotch pine are considered extremely desirable trees for landscape in the Midwest and elsewhere. *Diplodia* tip blight usually does not become serious on these trees until they reach 15-20 years of age. We can design these trees as limited-life landscape trees which can be removed and replaced after an extended time. In addition, these trees are often already installed in landscape designs which they will outgrow as the trees reach maturity. Crowded trees are more susceptible to *Diplodia* tip blight.

Diplodia Outlook

Although rainy spring weather is conducive to disease development, *Diplodia* tip blight seems to be becoming more prominent each season regardless of weather conditions. Certainly the disease incidence and severity will be increased during conducive conditions. But as the millions of Scotch and Austrian Pines which were planted many years ago reach maturity, we can expect more severe damage to the trees. If you require help in identifying the disease or further information regarding control, please feel free to contact me at the address below:

Dr. David L. Roberts, Director
Plant and Pest Diagnostic Clinic
Michigan State University
East Lansing, MI. 48824-1312
PH. 517/355-4536
FAX 517/353-1781

The research on *Diplodia* tip blight was supported by the Michigan Nursery and Landscape Association.

DIAGNOSING TREE PROBLEMS

Dr. D. L. Roberts
MSU Plant and Pest Diagnostic Clinic

An increasing number of tree problems with "nebulous causes" are being submitted to the MSU Plant and Pest Diagnostic Clinic. Often, a few dried, brown leaves from trees are submitted in an envelope and represent an entire maple tree problem. Unfortunately after these leaves are processed through the mechanical cancelers at the post office, my staff has mistaken them for tea leaves and have made their favorite beverage during their coffee breaks. In other instances, dead twigs containing brown leaves are submitted. Usually these are little better samples for diagnosis of problems associated with an eighty foot oak tree. (Incidentally, dead twigs do not make good tea!)

Confounding the above poor samples is the fact that little information about the tree accompanies the samples. After making several site visits I have discovered that solving tree problems may be exceedingly difficult. I hope to provide you with some tips on examining tree problems which will help you submit good samples and help us diagnose your problems. Before submitting samples consider the following questions:

* **What is the size and age of the tree? (Estimates are fine as long as they are reasonable).**
* **How often are the trees watered? What method of irrigation? ("Rain only" is an OK answer).**
* **How often are the trees fertilized? In what manner?**
* **When did symptoms appear? "Yesterday" is usually not a good answer because while tree problems may develop over a period of weeks, months and years are most likely.**
* **Have any chemicals been used on or near the trees? Herbicides, insecticides, fungicides?**
* **Are any cankers evident on the trunk? For some unknown reason people tend to ignore the large or small sections of bark that are peeling from the main trunk, particularly near the soil**

line. In some cases "lawn mower blight" or "weed trimmer canker" are responsible.

* **Have the roots been disturbed? i.e. Have flowers or shrubs been planted under the tree?**
* **Are any girdling roots present?**
* **Have there been any changes to the grade or local terrain?**
* **Has the water table changed in the past few months or years?**
* **Is this a new home site amongst an older stand of trees?**
* **Has any construction occurred recently?**

Many factors other than diseases and insects may cause decline and death of trees. In some instances, diseases and insect pests may be found directly on the leaves and twigs. In an increasing number of cases, the problem is associated with disorders **lower on the tree.** The rule with tree problem diagnosis is: **Any trunk or root problem will almost always result in a browning of the leaves.** I have visited sites in which heavy equipment was continually operated over the roots of large trees causing severe compaction during old house renovation or new house construction. I have visited sites in which several inches of "fill dirt" were placed over the roots of existing grand old trees. "Lawn mower blight" may permit attack by *Verticillium* (wilt), *Armillaria* root rot, *Phytophthora* bleeding canker and a host of other diseases which cannot be detected by leaf or twig analysis. Many of these problems result in a slow decline over a number of years. When submitting questions or samples to Michigan State University Extension at the county offices or to the MSU Plant and Pest Diagnostic Clinic, please consider the above information.

If you have any questions or comments, please feel free to contact me at 517/355-4536.

Canker Sores on Trees?

Dave Roberts, MSU Plant Diagnostic Clinic

Due to the extent of winter injury to trees and shrubs this year, many bare, dead branches exist in our landscapes. These dead branches appear "tasty" to a canker fungus. Instead of having the common names like Tom, Jeff, Jill, or Norbid, these canker fungi have names like *Nectria*, *Thyronectria*, *Botryosphaeria*, *Cytospora*, *Valsa*, and *Guignardia*, to name just a few of potentially thousands. Never name your offspring after these fungi unless you intend for them to be Plant Pathologists like me, Dave Bot Rot Roberts.

These fungi are often considered "weak pathogens." They prefer to colonize (=eat) stressed or dying or wounded wood tissue. Once wood tissue has been colonized and these fungi produce zillions of spores, they can gain sufficient strength to attack healthy tissue. Hence once established in their "squatter's rights," these fungi may cause severe canker damage on trees and shrubs for many years.

I have received many calls from folks who wonder when or whether dead limbs should be pruned from trees and shrubs. Following are some helpful hints:

* **Prune dead wood anytime except during wet weather. (The best time to prune healthy wood i.e. fruit trees, is during the late winter when disease organisms are inactive, from a plant pathologist viewpoint).**
* **Preferably prune dead wood from the plant by pruning into the green wood.**
* **For the least chance of transmitting disease, sterilize pruners with alcohol or other disinfectants between pruning or "every so often."**
* **Determine viability—dead wood will exhibit a brown, dry cambium layer beneath the bark; viable wood will be green and succulent.**
* **Do not remove entire shrubs or trees without testing for viability. Many shrubs will sprout from lower stems and recover more quickly than new installations.**
* **Tree paints have not been proven to be beneficial as wound dressings. Allow the wounds to heal naturally.**
* **Fungicide sprays are usually not recommended unless twig cankers caused by anthracnose-type fungi are the cause of the dieback.**